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COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
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Comprehensive Study of Water and Related Land Resources

Puget Sound and Adjacent Waters

State of Washington

Appendix VI
Municipal and Industrial Water Supply

Puget Sound Task Force—Pacific Northwest River Basins Commission

March 1970

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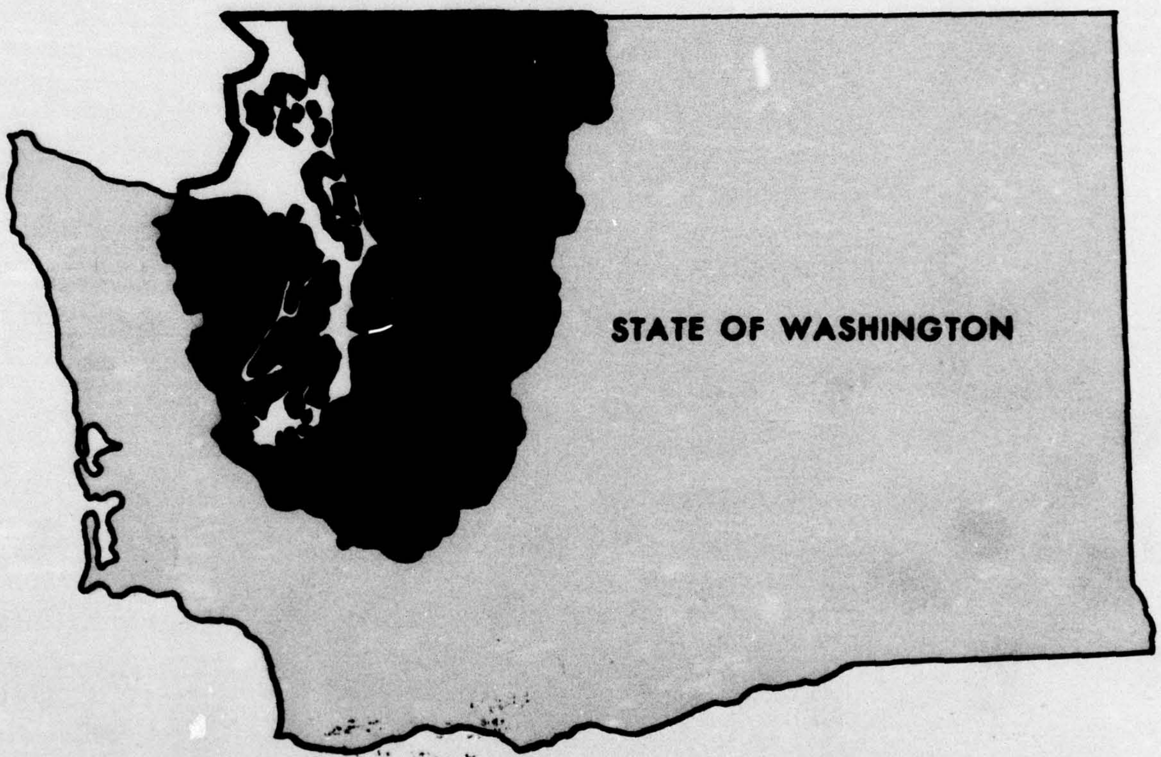

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Comprehensive Study of Water and Related Land Resources.

Puget Sound and Adjacent Waters,

APPENDIX VI.

MUNICIPAL AND INDUSTRIAL WATER SUPPLY,

10 Alfred T. Neale, Sydney Steinborn, Lewis F. Kehne, Ernest E. Allen, Francis L. Nelson

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ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE.

Municipal and Industrial Water Supply and Water Quality Control Technical Committee

PUGET SOUND TASK FORCE of the PACIFIC NORTHWEST RIVER BASINS COMMISSION

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FOREWORD

Appendix VI, Municipal and Industrial Water Supply, contains a detailed report of one component of the Comprehensive Water Resource Study of Puget Sound and Adjacent Waters. It is one of the technical appendices providing supporting data for the overall water resource study.

The Summary Report is supplemented by 15 appendices. Appendix I contains a Digest of Public Hearings. Appendices II through IV contain environmental studies. Appendices V through XIV each contain an inventory of present status, present and future needs, and the means to satisfy the needs, based upon a single use or control of water. Appendix XV contains comprehensive plans for the Puget Sound Area and its individual basins and describes the development of these multiple-purpose plans including the trade-offs of single-purpose solutions contained in Appendices V through XIV, to achieve multiple planning objectives.

The purpose of this appendix is to: (1) appraise the present use of water for municipal and industrial purposes in the Puget Sound Area; (2) determine the future water supply needs; and (3) present single-purpose means to meet these foreseeable short- and long-term needs.

River-basin planning in the Pacific Northwest was started under the guidance of the Columbia Basin Inter-Agency Committee (CBIAC) and completed under the aegis of the Pacific Northwest River Basins Commission. A Task Force for Puget Sound and Adjacent Waters was established in 1964 by the CBIAC for the purpose of making a water resource study of the Puget Sound based upon guidelines set forth in Senate Document 97, 87th Congress, Second Session.

The Puget Sound Task Force consists of ten members, each representing a major State or Federal agency. All State and Federal agencies having some authority over, or interest in, the use of water resources are included in the organized planning effort.

The published report is contained in the following volumes.

SUMMARY REPORT

APPENDICES

- I. Digest of Public Hearings
- II. Political and Legislative Environment
- III. Hydrology and Natural Environment
- IV. Economic Environment
- V. Water-Related Land Resources
  - a. Agriculture
  - b. Forests
  - c. Minerals
  - d. Intensive Land Use
  - e. Future Land Use
- VI. Municipal and Industrial Water Supply
- VII. Irrigation
- VIII. Navigation
- IX. Power
- X. Recreation
- XI. Fish and Wildlife
- XII. Flood Control
- XIII. Water Quality Control
- XIV. Watershed Management
- XV. Plan Formulation

APPENDIX VI
MUNICIPAL AND INDUSTRIAL WATER SUPPLY

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FIGURES

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INTRODUCTION

Water for municipal and industrial use comprises about 55 percent of all water consumptively used in the Puget Sound Area, and commands major emphasis among all water uses. An abundance of high-quality water is one of several major reasons for the Area's rapid economic development. Industries locate where water is available, and population centralizes around these industrial complexes. Water supply systems then evolve to furnish the required water for municipal and industrial needs. This appendix points out that water in this Area, though plentiful, may not be an inexhaustible resource. Coordinated, systematic water use planning must accompany the expected rapid growth in the Area if available water resources are to supply the expected increased need.

PURPOSE AND SCOPE

This appendix reports the results of a detailed investigation of municipal and industrial water supplies and uses. Comparison of the supply and use data reveals that substantially more water is available than is presently being used. With adequate planning, sufficient water resources exist in the Area to meet the demand during the foreseeable future.

Information in this appendix illustrates present and future demands for municipal and industrial water, and describes in general terms how the demand is currently being met. The data presented are based upon a single-purpose use of the water resources for analysis with other water uses in developing the Comprehensive Plan. No attempt has been made to analyze in detail the adequacy of present supply systems. For methodology and development of the Comprehensive Plan see Appendix XV, Plan Formulation.

AREA DESCRIPTION

GENERAL

Climate and topography have influenced the history of supplying water to the 15,900 square mile Puget Sound Area, Figure 1-1. Land elevations range from sea level along the shores of Puget Sound to 14,410-foot Mount Rainier. Natural barriers—the Cascade and Olympic mountain ranges, which form the eastern and western boundaries—protect the Area from severe weather and induce precipitation to replenish the Area's extensive water supplies.

Geography

The Puget Sound Area, a glaciated trough, contains densely forested mountains and foothills and fertile, open valleys, flood plains, and deltas. Population and industry cluster mainly along the eastern shore of Puget Sound. The Sound is an inland sea comprising about 2,500 square miles of surface area dotted with islands. The islands range in size from Whidbey, second largest in the contiguous United States, with an area of 102,000 acres, to the smaller San Juans, an archipelago of 172 islands in the northern part of the Sound. Of the 13,367 square miles of land in the Puget Sound Area, 1,760 square miles are arable lowland plains and deltas, river valleys, midland terraces, and mountain-valley extensions. Most of the population, industry, and agriculture is concentrated on these lands. The rest of the land (11,607 square miles) consists of mountainous terrain that provides the watersheds and glaciers supplying the Area's rivers and streams. There is a total area of approximately 240 square miles of fresh water in the Puget Sound Area. Photo 1-1 shows part of a typical watershed development.

Climate

The Cascade Mountain Range forms a barrier to cold air masses traveling south from Canada in the winter; the Olympics provide a barrier to the intense winter storms reaching the coast from the Pacific Ocean. As a result, the Area has cool summers and mild winters. Temperatures below -18°C (0°F) are rare in the lowlands, and maximum temperatures seldom exceed 38°C (100°F). Lowland temperatures average about 4°C (40°F) in the winter and above 15°C (60°F) in the summer.

Annual precipitation varies from 20 to 50 inches in the lowlands surrounding Puget Sound to more than 200 inches in higher elevations. About

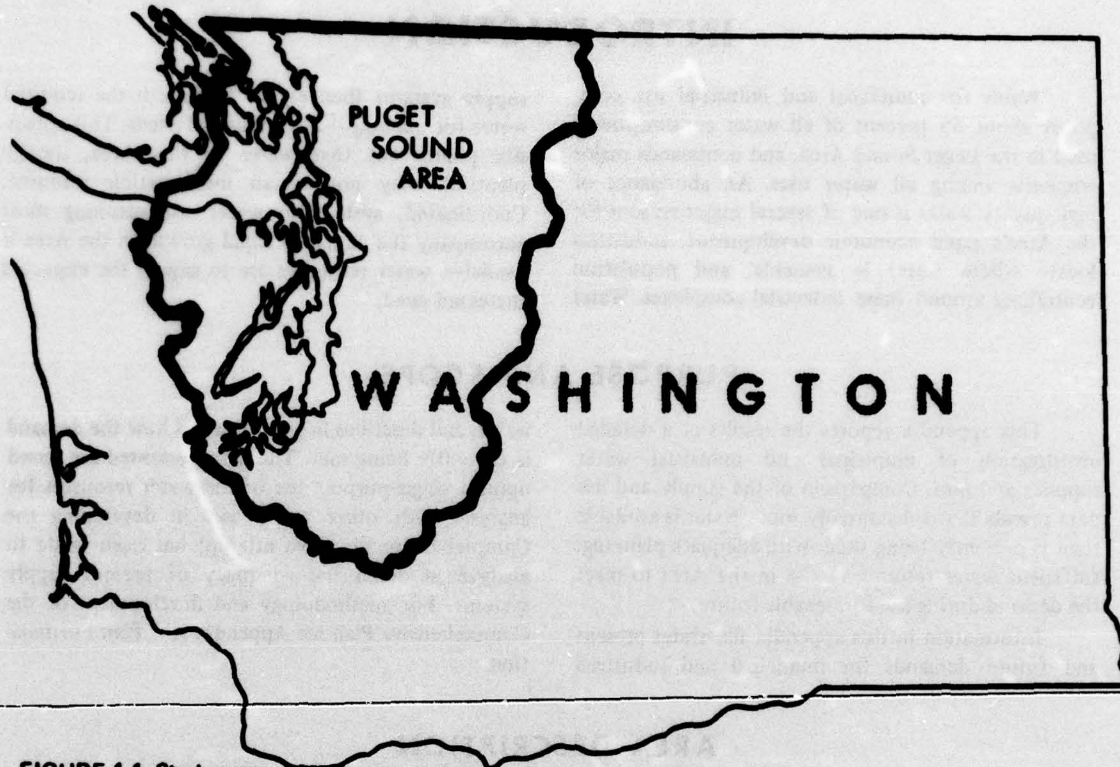


FIGURE 1-1. Study area.

two-thirds of all precipitation falls from October through March. Autumn, winter, and early spring are rainy, with persistent cloudiness and high relative humidity, but rainfall is scant from May through August.

History

An abundant supply of high-quality water has been a basis and incentive for the growing economy in the Puget Sound Area. Water supply systems have progressed with this expanding economy.

Early water supplies consisted of perennial streams, springs, and wells. For many years following the first settlements, pioneers obtained water from crude, uncoordinated private water systems consisting of wooden tanks and pipes. Water often flowed in open V-shaped flumes. Many of the distribution mains were inadequate in size; major fires resulted because insufficient flow was available for fire-fighting.

During the 1850's a Chinese man, Tom Quon, operated one of the first "distribution systems" in Tacoma consisting of a one-horse cart that carried a barrel of spring water. As the city grew, several small systems, including Tacoma Light and Water Company, evolved to supply water needs. General dissatisfaction with the quality and quantity of water and service rendered by these companies plus an expanding population led to the sinking of wells, and later to construction of the Green River gravity supply system.

Early distribution systems did not always protect the health of the population. Waterborne diseases were often a problem. Two major outbreaks of typhoid fever occurred in Seattle before the city ceased pumping local surface water.

The great Seattle fire of 1889, which destroyed the business district, demonstrated the inadequacy of that city's water supply system. Shortly after 1900, Seattle abandoned its pumping plant on Lake Washington—until then the primary water source—and

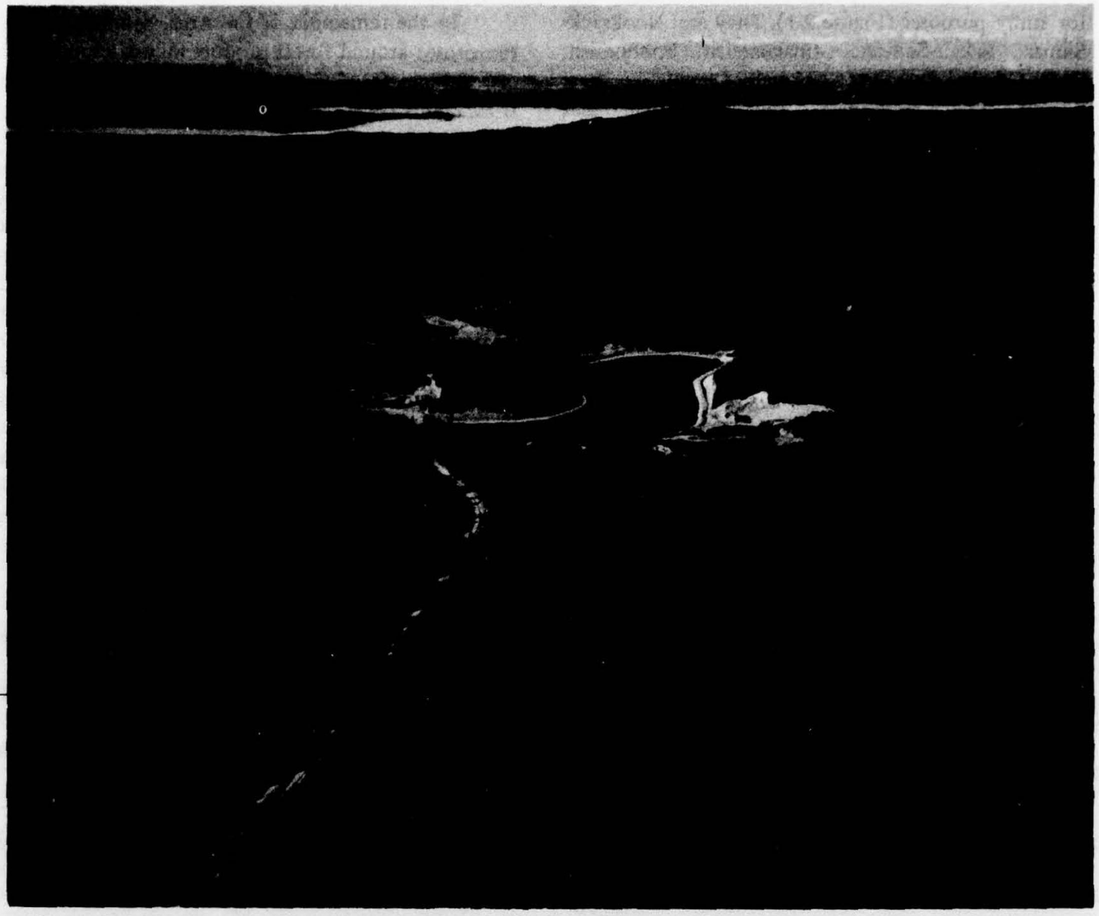


PHOTO 1-1. Watershed utilization includes such developments as this, which limits land use on slopes that drain into the river basin, thus protecting the quality of water captured for municipal and industrial use. (Tolt regulating basin, Seattle Water Department).

began drawing from the Cedar River watershed, 26 miles southeast of the city. The steady rise in population from 3,500 in 1880 to 43,000 in 1890 and 80,671 in 1900, and the availability of the less contaminated mountain water of the Cedar River, prompted development of the protected watershed and construction of a gravity supply system.

Around the turn of the century, other cities purchased local water companies and began to develop large public water supplies. Many communities acquired distant surface water rights to provide for the needs of expanding populations and industries. They developed watersheds with varying ownership and management to control pollution resulting from uncontrolled logging and abused public access.

At first, simple diversions from watersheds to the cities were sufficient, but as the population of the Area grew, dams were constructed to impound water, augmenting low stream flows and providing effective flood control. Today, supply systems vary from versatile networks serving large municipalities and metropolitan areas to simple distribution systems in small, scattered rural communities. Steady progress in developing high quality water sources, mainly from surface waters but with some pumping of ground waters, characterizes municipal and industrial water supplies throughout the Area.

BASINS

Natural topographic features were used to divide the Puget Sound Area into 11 drainage basins

for study purposes (Figure 2-1). They are: Nooksack-Sumas, Sakgit-Samish, Stillaguamish, Snohomish, Cedar-Green, Puyallup, Nisqually-Deschutes, West Sound, Elwha-Dungeness, and San Juan and Whidbey-Camano Islands. Ridgelines running from the slopes of the Cascade or Olympic mountains to Puget Sound bound each of these basins except the latter two, which are island groups. The other nine basins share similar topographic characteristics (Photos 1-2, 1-3, and 1-4): one or more rivers, mountainous terrain in the upper reaches, deep valleys and canyons in the central portions, and plains and deltas in the lowlands. The Cedar-Green, Skagit, and Snohomish Basins supply water for use outside their boundaries to meet the needs of the major water consumption centers of Seattle, Whidbey Island and Tacoma. Separate sections in this appendix describe water sources and use in each of the 11 basins.

PRESENT DEVELOPMENT

Forests cover more than 82 percent of the land in the Area. Urban build-up, which contains most of the population and economic activity, occupies only about 5 percent of the total acreage.

Economy

A dynamic industrial complex in the Snohomish, Cedar-Green, and Puyallup Basins accounts for much of the economic activity in the Area. In these basins, Seattle, Tacoma, and Everett contain a large and growing industrial community that is heavily oriented toward activities in aerospace, shipbuilding, maritime trade, transportation, and diversified manufacturing. The Boeing Company's aerospace industry constitutes the Area's leading industrial employer. These cities also serve as the major shipping and trading centers on Puget Sound, which has many inlets, bays, and harbors, and fine deep-water facilities for ocean-going vessels. Photo 1-5 shows an industrialized urban concentration.

Government activities also play a major role in the economy. The Puget Sound Naval Shipyard, second largest industrial employer in the Area, dominates the economy of Bremerton and the Kitsap Peninsula. McChord Air Force Base and Fort Lewis are major sources of personal income in the Tacoma area. Activities to provide government services contribute heavily to the economy of Olympia, the State capitol, and vicinity.

In the remainder of the Area, economic activities center around forest product industries, commercial fishing, farming, and miscellaneous light industries. Photo 1-6 is typical of habitable land away from urban centers.

An abundance of clean, relatively cheap water explains, in large part, the industrial growth in the Area. This growth shows an acceleration at an increasing rate since 1940. Accompanying the desirable effects of improved and expanded economic opportunities are changes in population distribution and further urbanization, increasing the demands on existing water sources, for municipal and industrial uses. In addition, the increase in population accompanying the economic growth produces additional demands for rural, urban and wilderness recreational sites. An accelerating need for recreational land is evident; this trend promises to continue as the Area becomes more industrialized.

Population

The population trend in the Puget Sound Area, in keeping with increased industrialization, displays rapid growth. Census figures show nearly a 10-percent increase between 1960 (1,768,000) and 1965 (2,100,000). Since 1940, the population has more than doubled.

Census estimates for 1966 include sixteen cities with populations greater than 10,000 (Table 1-1). The population trends of the seven largest of these sixteen cities from the earliest census to 1967 are shown in Figure 1-2.

TABLE 1-1. Cities with population over 10,000

	City	1967
1.	Seattle	580,000
2.	Tacoma	156,000
3.	Everett	52,000
4.	Bellingham	36,500
5.	Bremerton	36,164
6.	Renton	23,066
7.	Edmonds	21,800
8.	Bellevue	22,000
9.	Olympia	20,880
10.	Port Angeles	15,800
11.	Auburn	17,092
12.	Mercer Island City	16,500
13.	Mountlake Terrace	15,700
14.	Puyallup	14,200
15.	Kent	14,009
16.	Lynnwood	12,585

PHOTO 1-2. Mountains and forested foothills typify upper reaches.

PHOTO 1-3. Picturesque streams lie between the mountains and lowlands.

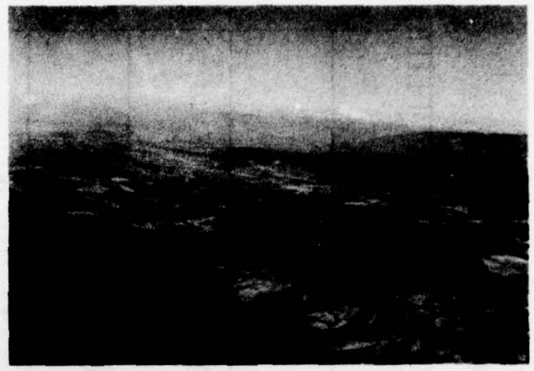


PHOTO 1-4. Deltas and open valleys, set off by rolling terraces, characterize lowlands.

PHOTO 1-5. Manufacturing, shipping, trading, and financial activities, with dense urban build-ups, center around natural and developed harbors.

PHOTO 1-6. Agriculture and forest harvesting support many small communities, which contain only a small percentage of the population.

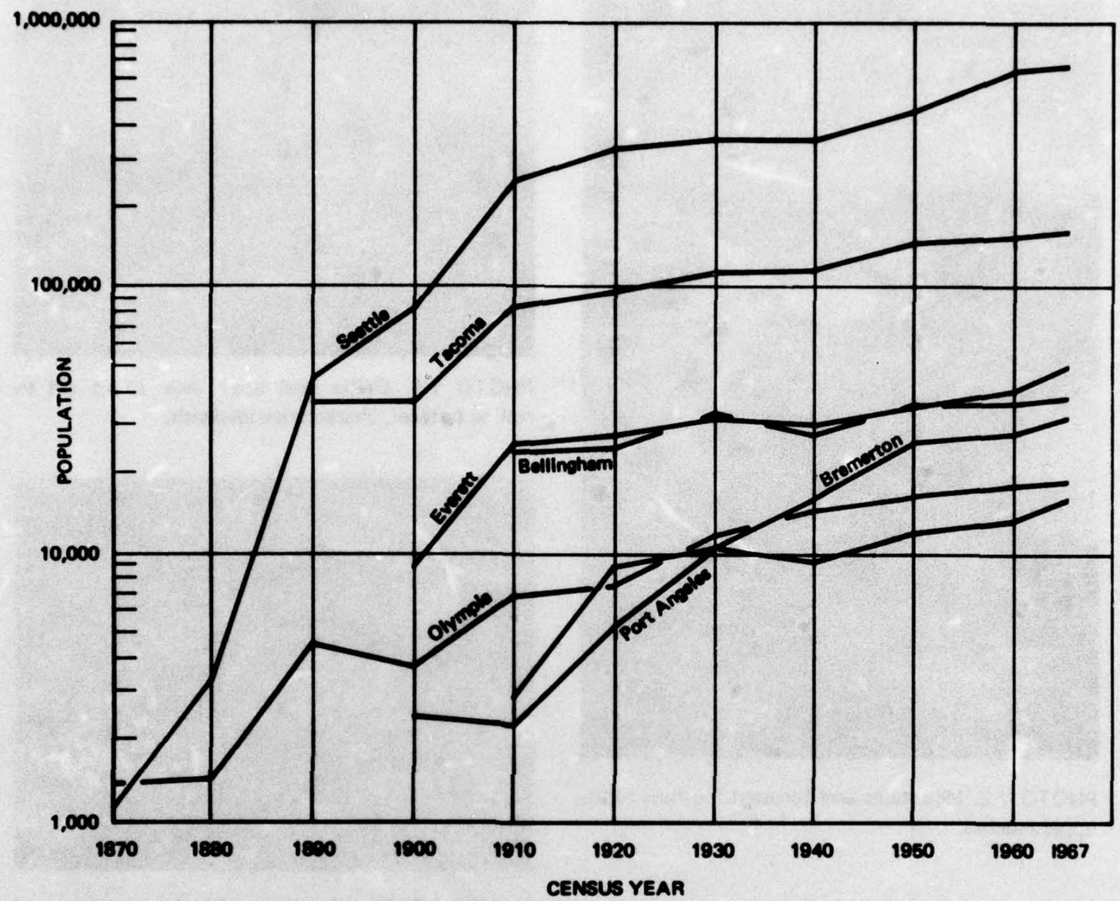


FIGURE 1-2. Major city populations (earliest census to 1967).

There is an uneven distribution of population in the Area; this results from differences in topography, accessibility, and recent industrialization. Nearly 75 percent of the populace reside in the Snohomish, Cedar-Green, and Puyallup Basins. The western and northern portions of the Area are sparsely populated. The Nisqually-Deschutes, West Sound, and Elwha-Dungeness Basins together account for only about 13 percent of the total population. Less than 12 percent reside in the Nooksack-Sumas, Skagit-Samish, Stillaguamish, San Juan, and Whidbey-Camano Basins.

The trend of rapidly increasing population and further localization of population will likely continue and will place an added burden on the water resources of the densely populated basin.

Land Use

Land use in the Puget Sound Area varies from dense residential, commercial, and industrial concentrations to undeveloped cutover lands and virgin forests. Forest lands predominate, accounting for 84 percent of the total land (excluding water surface, Photo 1-7). Most forest acreage lies within the boundaries of federally owned national forests and national parks. Urban areas are almost entirely on the lowlands along Puget Sound. Cropland predominates along the rivers and especially along their lower reaches. Table 1-2 shows land use in the Area.

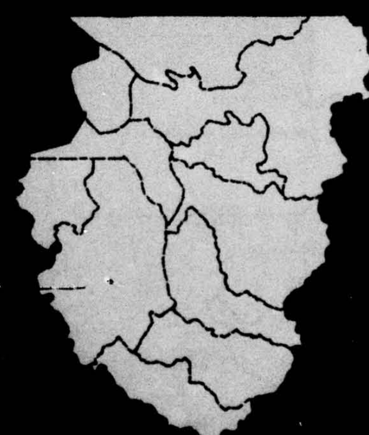
PHOTO 1-7. Fresh water, including river and stream-beds, covers nearly 2 percent of the land.

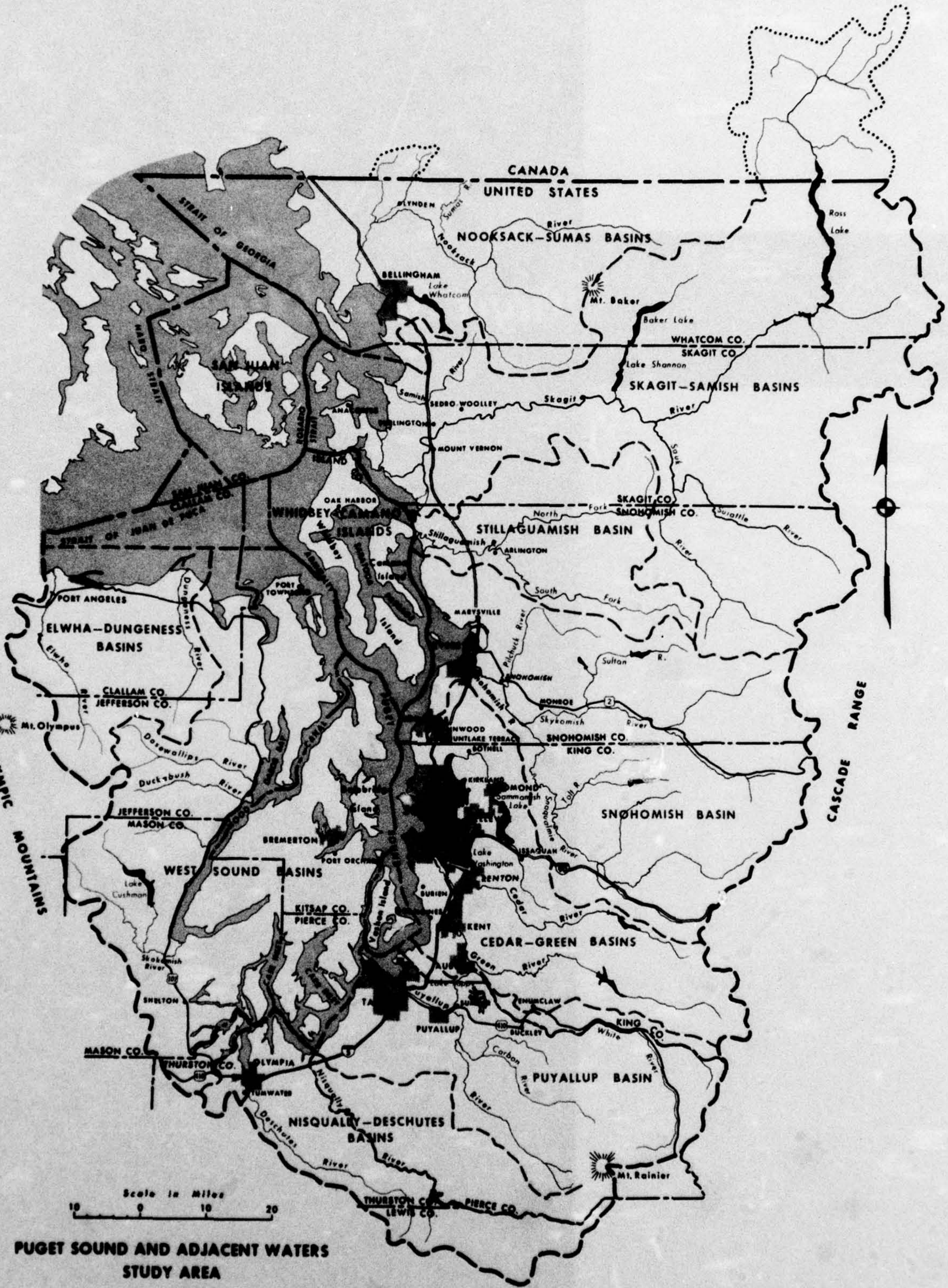
TABLE 1-2. General land use

Type	Acres
Rangeland	105,000
Water (stream beds, lakes, reservoirs)	153,000
Urban build-up	428,000
Cropland	591,000
Rural and nonagricultural	238,000
Forest land (including open and barren land associated with forest land	7,040,000
Total land and water (except salt water)	8,555,000

Source: Appendix III, Hydrology.

Puget Sound Area





PUGET SOUND AND ADJACENT WATERS STUDY AREA

FIGURE 2—1. Basins in the Puget Sound Area

PUGET SOUND AREA

PRESENT STATUS

Both ground and surface water sources, the latter predominating, serve the demands for various uses in the Area. Photo 2-1 shows one source of surface water.

PHOTO 2-1. Watersheds funnel precipitation into streams and rivers, from where it is drawn to supply demand.

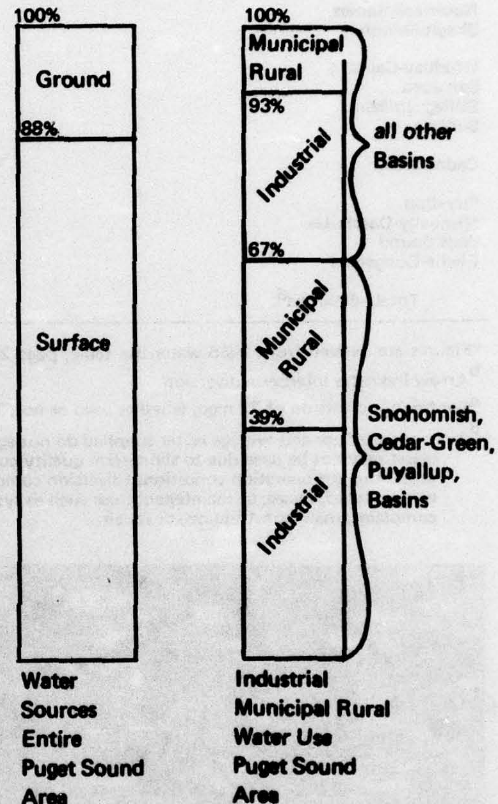


FIGURE 2-2. Water source and use characteristics (1965).

GENERAL

Water supplies for municipal, industrial, rural-individual and recreational purposes are considered in this report. This usage accounts for 659 million gallons per day (mgd). Figure 2-2, which shows use characteristics, reveals that most of the municipal and industrial water supplied in the Area is used in three basins. Appendix III, Hydrology and Natural Environment Supplement; Water Rights, defines and describes all purposes of use.

Table 2-1 compares water used in each basin for municipal and industrial purposes with water supplied from each basin for these purposes. As indicated, interbasin diversions from three basins serve users in other basins. The Snohomish and Cedar-Green Basins account for more than 50 percent of the water use in the Area but furnish more than 60 percent of the water supplied.

Water is relatively inexpensive in most places within the Puget Sound Area, compared to the national average. In particular, industries here have traditionally paid low rates for water, resulting in higher water use than in water-short areas where water is more expensive. In the Puget Sound Area, water rates and municipal per capita water use both tend to decrease as the municipality size increases. Nationally, average water rates follow this pattern, but per capita water use does not, tending to increase in larger cities.

Re-use of water is virtually unknown in the Puget Sound Area. The long-standing pattern is to divert water from mountain watersheds, Photo 2-2, convey it to the population and industrial complexes for use, then dispose of waste water in Puget Sound.

TABLE 2-1. Summary of municipal and industrial system supplies and use (1965)

Basin	Average daily water use (mgd)[a]	Average daily water supplied from basin (mgd) Surface	Ground	Total
Nooksack-Sumas	72.4	69.0	3.4	72.0
Skagit-Samish	29.0	27.0	1.6	31.0
		2.5[b]		
Whidbey-Camano	3.8	--	1.3	1.3
San Juan	0.6	0.4	0.2	0.6
Stillaguamish	2.2	0.2	2.1	2.3
Snohomish	164.0	161.0	2.8	197.0
		33.0[b]		
Cedar-Green	165.0	115.0	17.0	204.0
		72.0[bc]		
Puyallup	100.0	1.0	37.0	38.0
Nisqually-Deschutes	9.0	1.0	8.0	9.0
West Sound	48.0	38.0	11.0	49.0
Elwha-Dungeness	65.0	64.0	1.0	65.0
Total, all basins[d]	659.0	584.0	85.0	669.0

[a]Figures are derived from 1965 water use table, page 2-3.

[b]Arrow indicates interbasin diversion.

[c]Continuous diversion of 72 mgd, whether used or not, Tacoma Water Division.

[d]Average water use and average water supplied do not agree in totals since diverted water may not be used due to short-term quality conditions (for example, turbidity) or continuous operation conditions (diversion completely on or off, with excess water wasted; losses; or maintenance use such as system flushing after odor complaint, main construction, or repair.

PHOTO 2-2. Upriver diversions and reservoirs tap the abundant water resources for conveyance to high-use localities. (Green River diversion at Palmer, Tacoma Water Department).

The large quantities of low-cost water available and the particular locational pattern essentially obviate water re-use. Table 2-2 summarizes 1965 municipal and industrial water use.

Municipal

Municipal water use is defined as water served by a public or private purveyor through a distribution system. Included are residential, commercial, and public uses, and minor industrial uses directly related to goods and services for the local population. The latter, therefore, are included in the municipal gallons per capita per day (gpcd) use figures.

Municipal water use presently averages 219 mgd, as shown in Table 2-2, with about half of that total being used by Seattle. Municipal use constitutes about one-third of the total water used by municipal and industrial consumers in the Area. Per capita water use varies from city to city because of a number of factors that influence the rate of use. Bellingham, for example, meters very few of its deliveries and has an exceptionally high rate of water use, in part, because some of the water supplied to industrial users cannot

TABLE 2-2. Summary of Puget Sound Area water use (1965)

Basin and use	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Estimated population served	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Estimated population served	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
NOOKSACK-SUMAS									
Municipal	42,600	9.0	13.0	16,800	1.9	2.6	59,400	10.9	16.0
Rural-Individual	1,500	0.1	0.2	16,500	0.9	1.8	18,300	1.0	2.0
Industrial	---	60.0	65.0		0.6	1.2	---	60.6	66.0
Total	44,400	69.0	78.0	33,300	3.4	5.6	77,700	72.4	84.0
SKAGIT-SAMISH									
Municipal	34,400	3.5	4.2	5,800	0.8	1.1	40,200	4.3	5.0
Rural-Individual	1,550	0.1	0.2	13,750	0.8	1.6	15,300	0.9	2.0
Industrial	---	23.0	27.0	---	---	---	---	23.0	27.0
Total	35,950	27.0	31.0	19,545	1.6	2.7	55,500	29.0	34.0
STILLAGUAMISH									
Municipal	665	0.1	0.1	6,135	0.9	1.5	6,800	1.0	2.0
Rural-Individual	1,200	0.1	0.1	10,900	0.6	0.9	12,100	0.7	1.0
Industrial	---	---	---	---	0.6	4.0	---	0.6	4.0
Total	1,865	0.2	0.2	17,035	2.1	6.4	18,900	2.2	7.0
WHIDBEY-CAMANO ISLANDS									
Municipal	4,800	1.0	1.4	11,385	1.1	2.2	16,185	2.1	3.6
Rural-Individual	---	---	---	4,015	0.2	0.4	4,015	0.2	0.4
Industrial	---	1.5	1.8	---	---	---	---	1.5	1.8
Total	4,800	2.5	3.2	15,400	1.3	2.6	20,200	3.8	5.8
SNOHOMISH									
Municipal	147,930	23.0	28.0	6,530	0.6	1.2	154,760	24.0	29.0
Rural-Individual	3,540	0.2	0.3	32,400	1.8	2.5	35,940	2.0	3.0
Industrial	---	138.0	144.0	---	0.4	0.7	---	138.0	145.0
Total	151,470	161.0	172.0	39,230	2.8	4.4	190,700	164.0	177.0
CEDAR-GREEN									
Municipal	899,420	94.0	133.0	125,800	14.0	21.0	1,025,220	108.0	154.0
Rural-Individual	1,500	0.1	0.1	13,500	0.8	1.0	15,000	1.0	1.0
Industrial	---	54.0	61.0	---	2.3	2.7	---	56.0	64.0
Total	900,920	148.0	194.0	139,300	17.0	25.0	1,040,220	165.0	219.0
PUYALLUP									
Municipal	151,200	22.0	29.0	193,255	22.0	98.0	344,455	44.0	127.0
Rural-Individual	75	---		670	0.1	0.1	745	0.1	0.1
Industrial	---	41.0	49.0	---	15.0	16.0	---	56.0	65.0
Total	151,275	63.0	78.0	193,925	37.0	115.0	345,200	100.0	193.0
NISQUALLY-DESCHUTES									
Municipal	11,680	0.6	1.3	35,209	4.8	8.7	46,389	5.0	10.0
Rural-Individual	2,300	0.1	0.2	20,600	1.1	1.6	22,900	1.2	1.8
Industrial	---	0.2	0.2	---	2.0	2.4	---	2.2	2.7
Total	13,980	1.0	2.0	55,809	8.0	13.0	69,300	9.0	14.0
WEST SOUND									
Municipal	44,555	7.3	11.6	64,695	7.1	14.6	109,250	14.0	26.0
Rural-Individual	1,250	0.1	0.1	11,400	0.9	1.3	12,650	1.0	1.4
Industrial	---	30.6	42.5	---	3.2	3.8	---	34.0	46.0
Total	45,850	38.0	54.0	76,095	11.0	19	121,900	48.0	73
ELWHA-DUNGENESS									
Municipal	17,672	4.6	8.2	323	---	---	18,000	4.6	8.2
Rural-Individual	1,200	0.1	0.1	10,800	0.5	0.7	12,000	0.6	0.8
Industrial	---	59.2	64.9	---	---	---	---	59.0	65.0
Total	18,872	64.0	73.0	11,123	1.0	1.0	30,000	65.0	74.0
SAN JUAN ISLANDS									
Municipal	1,642	0.4	0.9	746	0.2	0.3	2,388	0.6	1.2
Rural-Individual	---	---	---	212		---	212	---	---
Industrial	---	---	---	---	---	---	---	---	---
Total	1,642	0.4	0.9	958	0.2	0.3	2,600	0.6	1.2
TOTALS[a/]									
Municipal	1,356,550	165	231	467,000	53	151	1,823,550	219	382
Rural-Individual	14,450	1	1	134,700	8	12	149,150	9	13
Industrial	---	407	455	---	24	31	---	431	486
Total	1,371,000	573	687	601,700	85	194	1,972,700	659	881

[a/] Figures are rounded

be segregated from that supplied for municipal use. Total average daily municipal water use in the Puget Sound Area, for a served population of 1,823,000, is about 120 gpcd. Table 2-3 shows present municipal per capita water use (gpd) for the major cities in the Area.

TABLE 2-3. Municipal per capita water use G.P.C.D. in major water systems (1965)

Basin	System	Estimated population served	Average daily water use (gpcd)[a]
Nooksack-Sumas	Bellingham	40,000	220
Skagit-Samish	Anacortes	10,000	140
Snohomish	Everett	135,000	160
Cedar-Green	Seattle	887,000	130
Puyallup	Tacoma	158,000	140
Nisqually-Deschutes	Olympia	22,600	120
West Sound	Shelton	5,800	170
	Bremerton	42,000	160
	Port Townsend	7,500	200
Elwha-Dungeness	Port Angeles	15,700	240
Total (weighted average)		1,324,000	140

[a]Excludes major water-using industries.

Adequacy of water to be ingested by human is determined by a series of quality parameters which describe its physical, chemical, and bacteriological characteristics. In addition, the source of these waters should be subjected to periodic sanitary surveys by qualified public health authorities to determine if any potential hazards exist.

Quality criteria for public drinking water use have been developed by the water works industry and public health authorities through years of experience. Although these criteria may vary from state to state or region to region, depending upon local contaminants, there has been almost universal acceptance of the "Drinking Water Standards" promulgated by the Public Health Service. These Standards, initially adopted in 1914 for potable water used by common carriers subject to the Federal Quarantine Regulations, have been periodically expanded and updated, with the latest revision being made in 1962. This revision was officially endorsed by the American Water Works Association as minimum standards for all public water supplies.

Although drinking water standards are applicable to water as it comes from the tap, complete conventional treatment including disinfection generally produces little change in raw water quality characteristics except some physical and bacteriological parameters and a few dissolved chemical constituents, such as iron and manganese. Therefore, recommended limits for trace metals, radioactivity and pesticides in the raw water are the same as those for finished water regardless of treatment provided and should be used as criteria in selecting sources or treatment of a raw water supply. The following is a list of some of the more important dissolved chemical constituents and their respective recommended maximum concentrations.

Substance	Concentration (mg/l)
Arsenic (As)	0.01
Barium (Ba)	1.0
Boron (B)	1.0
Cadmium (Cd)	0.01
Carbon Chloroform Extract (CCE)	0.2
Chloride (Cl)	250
Chromium (hexavelent, Cr^{+6})	0.05
Copper (Cu)	1.0
Cyanide (CN)	0.01
Detergents (Methylene Blue Active Substances)	0.5
Fluoride (F)	
50.0-58.3°F	1.8
58.4-70.6°F	1.5
70.7-90.5°F	1.2
Iron (Fe)	0.3
Lead (Pb)	0.05
Manganese (Mn)	0.05
Nitrogen (in nitrate or nitrite form)	10.0
Phenols	0.001
Selenium (Se)	0.01
Silver (Ag)	0.05
Sulfate (SO_4)	250
Total Dissolved Solids	500
Uranyl Ion (UO_2++)	5.0
Zinc (Zn)	5.0

Other characteristics which may have deleterious physiological effect or which may be excessively corrosive to the distribution system should not be permitted in the raw water supply.

Acceptability of drinking water from a radioactivity standpoint is generally monitored by

routinely measuring its gross beta activity and periodically analyzing for two of the more common specific contaminants, Radium-226 and Strontium-90. Recommended limits for these criteria are:

Substance	Concentration (pico curries per liter-pc/l)
Ra^{226}	3
St^{90}	10
Gross Beta	1,000

A wide variety of synthetic organic substances have been developed to control nuisance insect and plant growths. Many of these compounds have found their way into our waterways and have caused limits for these substances in drinking water to be established. Some of the more common pesticides and their corresponding limiting concentrations are presented as follows:

Pesticide	Maximum Permissible Concentration mg/l
Endrin	0.001
Aldrin	0.017
Dieldrin	0.017
Lindane	0.056
Toxaphene	0.005
Heptachlor	0.018
Heptachlor Epoxide	0.018
DDT	0.042
Chlordane	0.003
Methoxychlor	0.035
Total Organophosphorous and Carbamate Compounds (expressed in terms of Parathion Equivalent cholinesterase inhibitions)	0.1
2,4,5-TP 2,4,5-T 2,4-D	Individual limits = 0.1 mg/l. Sum of any combination of chlorinated phenoxy alkyl pesticides = 0.1 mg/l.

The physical characteristics of a raw water supply are, for the most part, alterable through conventional treatment processes, and different limits are recommended, depending upon the type of treatment provided. The physical parameters usually used to measure the suitability of water for human consumption are color, odor (and taste), turbidity, and sometimes temperature. The latter criteria is primarily an aesthetic consideration, and the general rule is that drinking water temperature should be below 85°F and not more than 5°F above ambient temperatures. The other three, however, can have a significant impact on the suitability and treatability of waters for human consumption. Recommended limits for these criteria for treated and non-treated supplies are as follows:

Characteristic	No Treatment or Disinfection Only	Conventional Treatment
Turbidity (turbidity units)	5	Variable (depending upon treatability)
Color (color units)	15	75
Odor (threshold odor number)	3	5

The traditional method for evaluating the bacteriological quality of drinking waters has been identification of the coliform group of bacteria. Examination for these non-pathogenic organisms provides an indicator of the disease-producing potential of the water. The coliform group, however, contains subgroups not only of fecal origin, but also those that are found naturally in soil, on plants and insects and in older pollution sources. To estimate the probability of viable pathogens being present, therefore, the coliform and fecal coliform organisms should be measured (the latter being indicative of recent fecal pollution), but the data must be correlated with sanitary surveys to determine its significance. Since the conventional treatment processes are capable of meeting drinking water bacterial standards, the recommended limits are contingent upon treatment provided. The limits are monthly arithmetic averages based upon an adequate number of samples. The total coliform density limits may be exceeded if the fecal coliform limit is within the limits specified below:

Organism	No Treatment	Disinfection Only	Complete Treatment
Total coliform (per 100 ml)	0	100	20,000
Fecal coliform (per 100 ml)	0	20	4,000

Because the above criteria apply to water for human consumption, if the limits are met, these waters should be equally acceptable for food processing and most other municipal or industrial uses. For specialized uses such as boiler feed water, additional treatment to prevent excessive scale formation would be necessary; however, any additional specialized conditioning of these such waters would be minimal.

Industrial

Industrial water use averages about 431 mgd, which represents about 65 percent of the total used by municipal and industrial consumers. Of this amount, about 407 mgd, or 95 percent, is supplied from surface water sources. Part of the industrial water use is included in the municipal per capita use figure, as mentioned in the preceding paragraphs describing municipal use. A much larger portion, however, reflects the needs of a few large water-using industries that are not directly related to the local population. The size and location of these industries relate to such factors as access to raw material, access to market, power and labor costs, water supply, waste disposal, and economics of scale (plant size). Photo 2-3 shows a portion of a water system that supplies both municipal and industrial demand.

Table 2-4 summarizes the location, by basin, and the amount of water used by major industries. Many of the individual plants for industries shown in Table 2-4 obtain their water through municipal systems, and probably will continue to receive water from these systems. But their present demand and future needs are analyzed separately because their size and location are not directly related to total population and their water supplies could conceivably be independent of municipal supplies.

The pulp and paper industry is by far the most important in terms of the quantity of water used. This industry accounts for 72 percent of the total water used by all industries—an average demand of 313 mgd. Almost all water used in pulp and paper manufacturing comes from surface water sources.

The chemical, metal, and oil industries (including oil refining and primary metals) constitute the second largest water-using industrial group, accounting for 75.2 mgd (17.4 percent) of the total industrial water used. About 98 percent of this demand is supplied from surface water sources.

PHOTO 2-3. Storage facilities near the point of consumption furnish water for the immediate needs of users, large and small. (Water supply reservoir, Tacoma Water Department).

Cooling water makes up about 20 percent of the total industrial water use. Most of this is fresh water used in the petroleum and metal refining industries. About 84 percent of the total water used in these industries is for cooling. A high proportion (55 percent) of the water used in milk processing is for cooling, but the total quantity is comparatively minor.

Salt water, although not included in the water use accounting here, is used in significant quantities for cooling in the chemical, metal, oil, and pulp and paper industries. Salt water approximates 13 percent of all industrial water used in the Area.

TABLE 2-4. Summary of industrial water use (mgd) (1965).

Basin	Paper and allied	Oil refining	Food and kindred	Lumber and wood	Chemical, metals, oils	Stone, clay, glass	Primary metals	Other	Total
Nooksack-Sumas	46.4	2.8	2.5	—	—	—	8.0	0.8	60.5
Skagit-Samish	5.5	7.0	4.9	—	1.8	—	—	1.8	21.1
Stillaguamish	—	—	0.6	—	—	—	—	—	0.6
Whidbey-Camano Islands	—	—	—	—	—	—	—	1.5	1.5
Snohomish	134.0	—	1.8	2.2	—	—	—	1.2	139.2
Cedar-Green	—	—	4.3	4.8	40.5	1.0	—	6.2[a]	56.8
Puyallup	38.4	—	2.1	1.7	5.7	0.8	6.4	1.0	56.1
Nisqually-Deschutes	—	—	1.5	0.5	—	0.2	—	—	2.2
West Sound	29.7	—	—	1.2	2.9	—	—	—	21.1
Elwha-Dungeness	59.2	—	—	—	—	—	—	—	59.2
San Juan Islands	—	—	—	—	—	—	—	—	—
Total	313.2	9.8	17.7	10.4	50.9	2.0	14.4	12.5	430.8

[a]Transportation

Rural-Individual

About 150,000 persons in rural localities (Photo 2-4) rely on small individual systems such as wells or local surface sources for water supplies. No actual water use data are available for these systems; therefore, an average per capita figure of 55 gpd is assumed in determining this component. Estimates of rural-individual water use show consumption of 8.7 mgd, or about 1.3 percent of the Area's total municipal and industrial water use. Probably about 90 percent of the rural-individual population draw from ground-water sources, and the remaining 10 percent receive water from surface sources. Table 2-2 includes a summary of rural-individual water use.

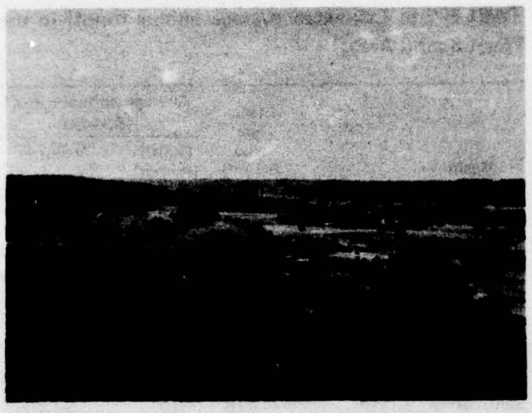


PHOTO 2-4. Most rural and small-community residents receive water from ground sources.

Recreational

Recreational demand for domestic water is an important factor in any plan concerned with providing adequate water supplies. Totals cited here for such demands were based on estimates by the Puget Sound and Adjacent Water Study's Recreation Technical Committee. Domestic water use relating directly to recreational activities in the Puget Sound Area averages 35 gallons per recreation man-days, for a total use of 2.275 billion gallons (an average of 6.23 mgd for the entire year). Recreational use, Photo 2-5, is seasonal, with summer months showing the highest consumption. Federal and State lands and urban parks account for a large part of this use.

This consumption is partially included in municipal and rural-individual water use. It is assumed that 30 percent of the demand from supplies in recreational sites is already included in the present status inventory. The balance of the recreational water requirements, or an estimated 4.4 mgd (25 gallons per recreation man-day), should be added to the municipal and rural-individual totals for the basins that contain these sites. Certain areas—notably National Forest and National Park recreation developments—account for a large part of this use.

PHOTO 2-5. Recreationists create a significant demand for water, both in wilderness surroundings and in more formal settings.

SURFACE WATER

Surface sources predominate as the major water suppliers in the Puget Sound Area. All major urban centers are relatively close to large quantities of high-quality surface water. Photo 2-6 shows a typical surface water source. More than 75 percent (615 mgd) of the municipally served persons and 94 percent (408 mgd) of all municipal and industrial consumers in the Area receive water from these sources, using about 553 million gallons of surface water per day. Present sources are more than adequate to satisfy existing and immediate future needs in most localities. The increased urbanization, indus-

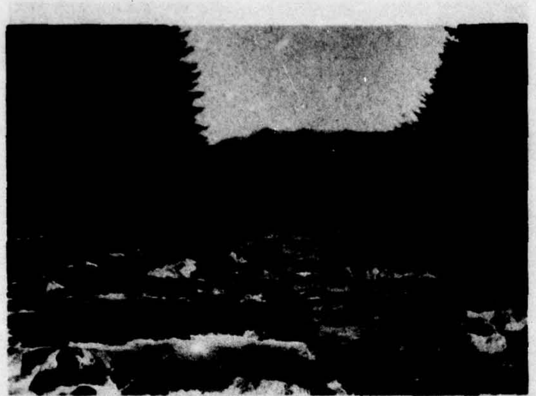


PHOTO 2-6. Surface water sources supply 88 percent of municipal and industrial water.

trialization, and population growth projected for the Area, however, requires that water resources be identified and that future demands, sources, and controls be determined so appropriate programs can be instituted to ensure an adequate supply of fresh, relatively inexpensive, clean water.

Quantity and Distribution

Analysis of the average runoff of all rivers in the Area provides an indication of surface water resources. Figure 2-3 shows the relative magnitude of the average discharge of the larger streams in the Area. Although some subsurface flow leaves the basins and is not measured as runoff, the quantity of water escaping in this manner is relatively insignificant in the larger watersheds. Surface runoff data, therefore, give a fairly accurate measure of the total surface water supply, including water released from natural storage (lakes and ponds) within the basins.

In the Puget Sound Area, the total runoff from 1931 to 1960 averaged about 39 million acre-feet annually, or an average of about 34.5 billion gallons per day. Despite the large total supply in the Area, however, water is not always available where and when it is needed to meet existing average and peak needs, and this situation probably will worsen with increased future needs. Average annual runoff ranges from less than 15 inches per unit area in some of the northern lowlands to as much as 140 inches in a few mountain localities. Table 2-5 lists the estimated average runoff for the 11 study basins.

Data in Table 2-5 for the various basins show a large disparity in average depth and volume runoff. The Skagit-Samish and Snohomish Basins contribute nearly half the total runoff in the Area. In addition to large annual differences in runoff, even larger variations occur with time. The sections of this appendix dealing with the individual basins describe seasonal variations in more detail. Fluctuations in runoff volume cause periods of flooding and periods of extreme lowflow. Thus, localized water shortages occur despite the abundant overall water supply, and periodic overabundance causes flood damage in some lowland localities. Studies of the frequency and severity of floods and lowflows are essential if water-management planning is to lessen the impact of such variations.

TABLE 2-5. Estimated average annual runoff in the Puget Sound Area.

Basin	Drainage area (sq mi)	Average annual runoff 1931-60 Depth (inches)	Average annual runoff 1931-60 Volume (acre-feet)
Nooksack-Sumas	1,262	55	3,700,000
Skagit-Samish	3,025	71	11,500,000[a]
Stillaguamish	690	80	2,940,000
Snohomish	1,900	70	7,090,000
Cedar-Green	1,151	36	2,210,000
Puyallup	1,217	41	2,660,000
Nisqually-Deschutes	1,016	36	1,950,000
West Sound	2,018	46	4,950,000
Elwha-Dungeness	690	45	1,660,000
Whidbey-Camano	209	10[b]	111,000[b]
San Juan	176	10[b]	94,000[b]
Total or average	13,355	55	38,865,000

[a]Does not include inflow from Canada.

[b]Estimated.

Source: Appendix III, Hydrology.

Quality

Surface water in the Area requires a minimum of treatment in order to produce an excellent quality water for industrial and municipal use. These waters require chlorination and some form of turbidity control. Turbidity is usually controlled by sedimentation in storage reservoirs. The more turbid waters are diverted away from impoundments. In some cases the melting of glaciers causes a turbidity which requires chemical treatment and filtration before an adequate water supply is realized. Increasing water quality standards and watershed usage is causing a trend toward filtration for surface water supplies. The low dissolved solids and low hardness are especially desirable from an aesthetic point of view in municipal supplies. These characteristics are also very important in industrial applications such as high dissolving wood pulps and steam boilers.

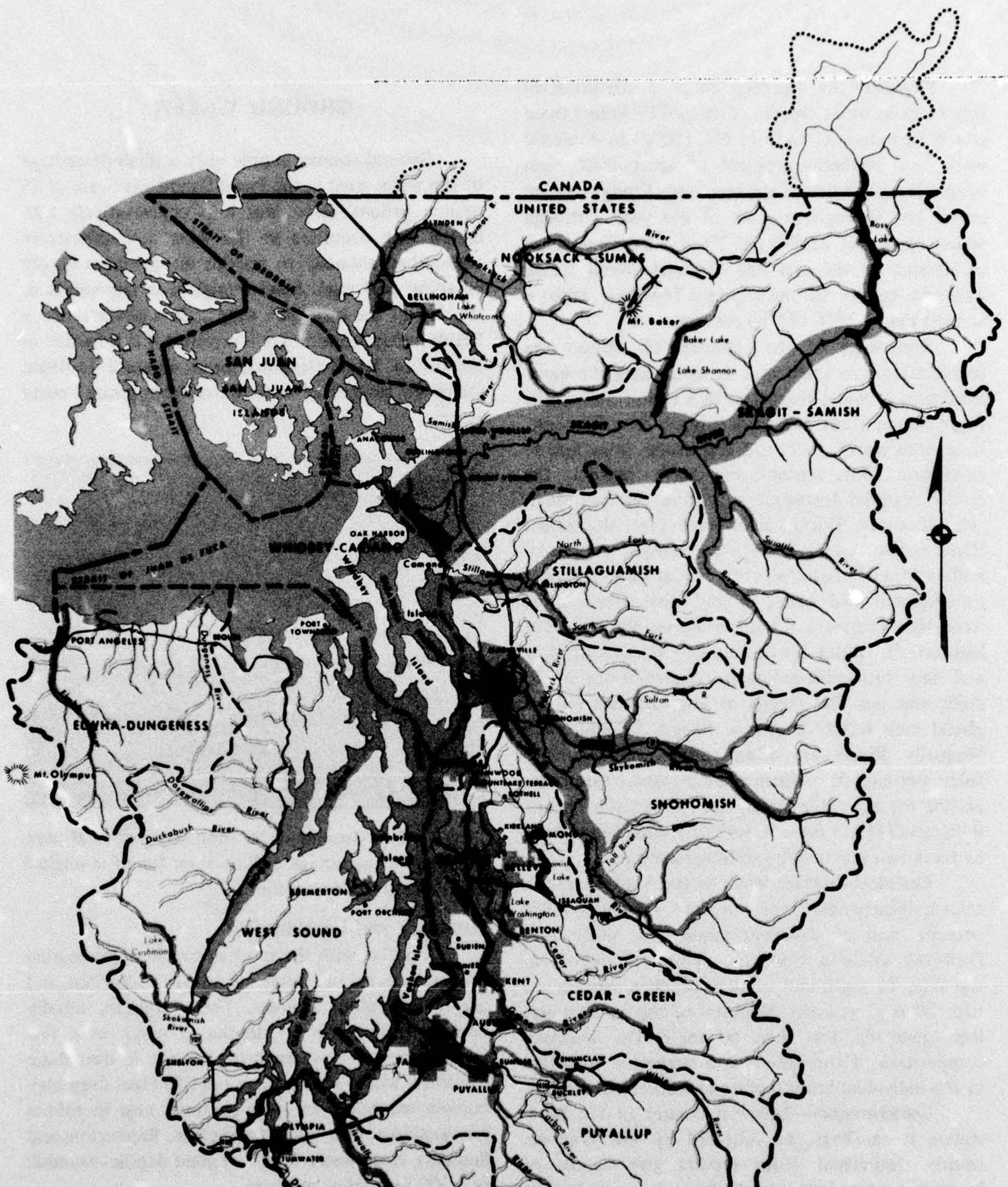


FIGURE 2-3. Average discharges of principal rivers.

Physical—The temperature of a stream is as important as other aspects of its quality. Where there is a temperature of over 15.6°C (60°F) in domestic water, an aesthetic problem of acceptability can occur. Temperatures of streams in the Study Area are rather low throughout most of the year, although values exceeding 23.9°C (75°F) have been measured in streams on the east side of Puget Sound during July and August. On the Olympic Peninsula, streams warmer than 21.1°C (70°F) are rare.

Knowledge of the processes of erosion and sedimentation is important in optimizing the beneficial uses of water resources. In a region such as the Puget Sound Study Area, where heavy rainfall occurs, large volumes of rock and soil erode from upland elevations. Swift streams and rivers transport the eroded material downstream, in some cases considerable distances. During an average year, the Skagit River, largest stream in the Area, transports about 10 million tons of suspended sediment, at least five times the sediment load carried by any other stream in the Area. Most sediment is transported during periods of high runoff. During lowflows, many streams are clear and have suspended-sediment concentrations of 20 milligrams per liter (mg/l) or less. Streams fed by glacial melt water—Nooksack, Skagit, Puyallup, and Nisqually Rivers—are often turbid and sediment-laden, particularly in warm weather. Where turbidities exceed the allowable limits, five (5) Jackson Turbidity Units (JTU) at present, turbidity must be removed by treatment plants or by settling reservoirs.

Chemical—Surface water in the Study Area is a calcium-bicarbonate type, of low dissolved solids content, and of excellent quality for most uses. Dissolved solids in most streams usually amount to less than 75 mg/l, and in some streams may be less than 20 mg/l at times. Hardness of the water is also low, generally less than 60 mg/l. The chemical composition of the various area streams is identified in the individual basin reports in succeeding sections.

Bacteriological—Bacterial quality in the headwaters is excellent, as indicated by low coliform counts. Individual basin reports give details of bacteria counts. Low counts are evident particularly in municipal watersheds where access is controlled. However, where agricultural drainage and municipal wastes are permitted to enter streams, bacterial counts increase significantly.

GROUND WATER

Ground sources supply only a small percentage of the water used in the Puget Sound Area—about 85 million gallons daily. But it is conservatively estimated that acquifers in the Area are sufficiently replenished annually to provide an optimum supply of about 650 mgd. Even though it is impossible to recover all the estimated supply, it is obvious that a largely untapped resource is available if it is needed in the future. Rural-individual users, Photo 2-7, obtain about 90 percent of their water from ground-water sources.

PHOTO 2-7. Ground water supplies most rural uses, including irrigation, as well as a portion of municipal and industrial consumption.

Quantity and Distribution

Aquifers with the most favorable water-bearing properties occur in recessional outwash, alluvium, and gravel and sand deposits. These aquifers usually contain fresh water at depths as much as a few hundred feet below sea level, except in near-shore localities, where aquifers less than 200 feet deep may contain sea water. In some localities near shorelines (for example, near Tacoma, Shelton, Bremerton, and Sequim), fresh water occurs at great depths—as much as 1,500 feet below sea level.

Opportunities for obtaining ground water in the Study Area are most favorable south of Seattle, where zones of water-bearing coarse sand and gravel in both recessional outwash and subtill strata are

relatively abundant in comparison to northern localities. In the region south of Seattle, ground water is used for municipal, irrigation, and industrial supply to a greater extent than farther north.

Figure 2-4 shows generalized well yields that may be expected in the Study Area. This profile is based largely on production of existing wells. Yields could be obtained locally that are either much greater or much less than shown by the map. The amount of ground water that can be recovered beneficially at a particular location depends on factors such as well spacing, thoroughness of well construction and completion, and potential deterioration of water quality. Appendix III, Hydrology and Natural Environment, contains detailed data on well yields.

Data on availability of ground water in the lowlands of each basin, except San Juan Islands, are based on estimates of natural recharge of aquifers by precipitation. The average annual recharge in the lowlands of the Study Area is conservatively estimated as 800,000 acre-feet. Although a large volume of water is available, certain problems might become critical as development of large ground-water supplies keeps pace with the expected increased demand. For example, high iron content and excessive hardness limit many industrial and domestic uses of ground water in some areas. Salt water encroachment, now detected only locally, could increase as a result of excessive pumping in shoreline localities. Bacterial contamination of shallow aquifers poses a problem in densely populated areas where individual household water supplies are taken from shallow wells and sewage is disposed of through septic tanks. The improper location or operation of refuse-disposal facilities could also cause serious ground-water contamination.

Quality

Much of the ground water in the Study Area is chemically satisfactory and of uniform low temperature. Dissolved solids are generally less than 200 mg/l, and hardness values are usually less than 80 mg/l. Ground-water temperatures are usually about 9°C (50°F). Iron content is objectionable in a few localities, particularly in river bottom areas. High iron content (more than 0.3 mg/l) has been reported also for well waters from some of the deeper aquifers. However, this is not necessarily representative of deeper zones, but may be the result of well construction that permits iron-bearing water to enter the well from shallow aquifers. In some localities near shorelines, ground water is highly mineralized because of the encroachment of sea water into fresh-water zones as a result of pumping. Potential sea water encroachment may be indicated by high concentrations of chloride. In general, chloride concentrations in ground water in the Area are less than 10 mg/l, but may be somewhat greater in localities underlaid by Tertiary Age rocks containing saline waters.

SOURCE DEVELOPMENT

General

Watershed areas totaling some 500 square miles, as shown on Figure 2-5, provide the major source of fresh water for the Puget Sound Area. As the region developed, encroachment on the watersheds became an increasing problem, and many cities, recognizing the requirements for the future, took steps to gain more positive control over these areas.

Seattle, Tacoma, and Bremerton gained control by outright purchases of portions of their watersheds. Seattle purchased the Cedar River watershed above Landsburg; Bremerton purchased portions of the Union River watershed; and Tacoma purchased 26 miles of river access on the Green River. Additionally, Seattle and Tacoma entered into agreements with large private timber holders and the U.S. Forest Service to provide management for and limit access to their watershed areas to ensure that adequate water quality is maintained. Photos 2-8 and 2-9 show watershed improvements.

Access to watersheds in the Area is limited in many cases by their remote locations and lack of roads. In addition, access through available roads is carefully controlled. Recreational use of the watersheds is discouraged, though completely restricted only in the Bremerton and Seattle watersheds. Logging activities in these areas are closely supervised, and other activities, such as summer cattle grazing, are strictly controlled.

The watersheds and ground water sources have been adequately developed to meet present needs throughout the Puget Sound Area. Their capability to provide sufficient water for future development varies widely from basin to basin, but only on the San Juan Islands and Whidbey Island are present sources near their ultimate capacity.

The Water Departments of Everett, Seattle, and Tacoma have tentatively agreed on service areas. These areas shown on Figure 2-5 by a water system division line appears to be the logical service areas to

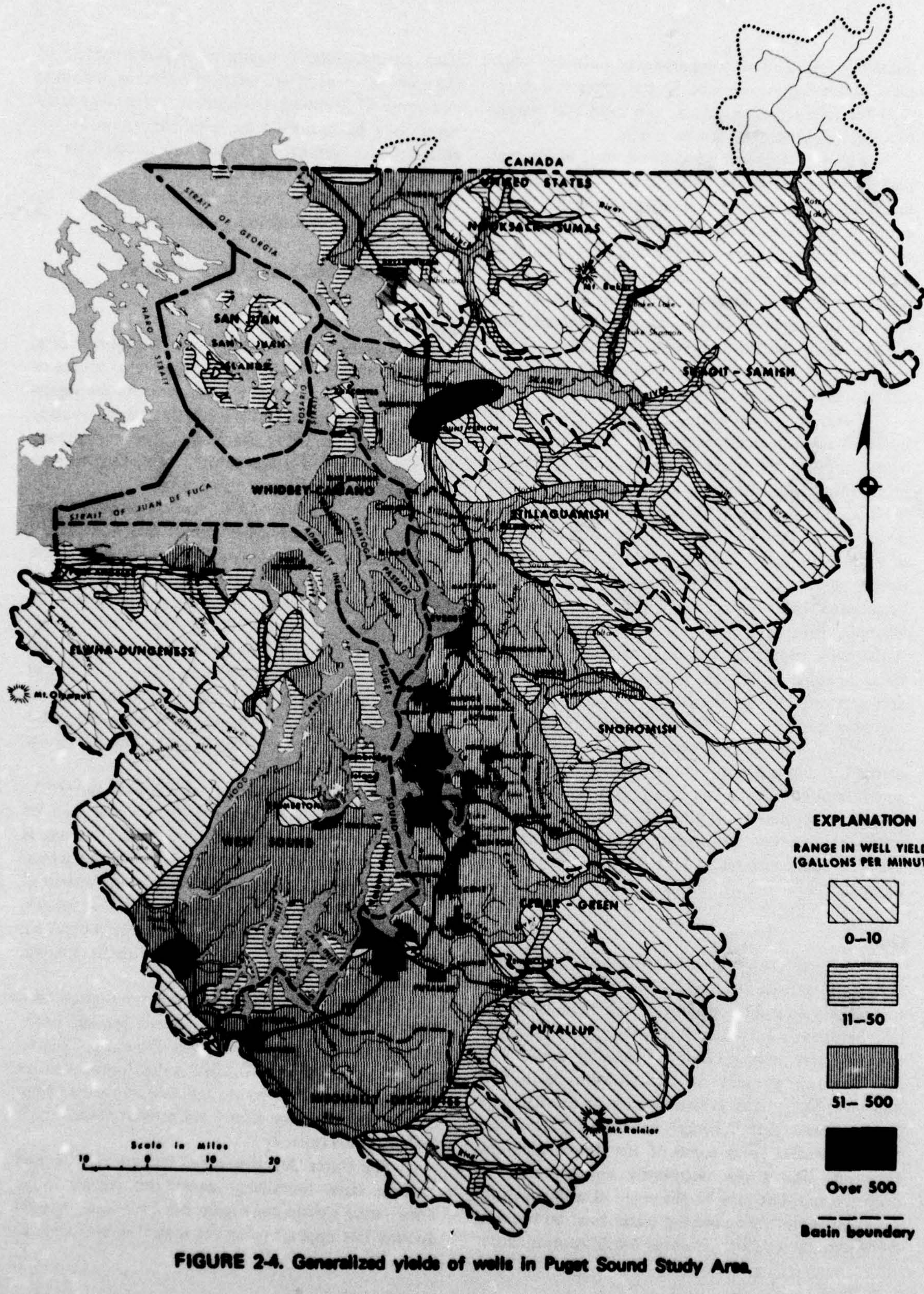


FIGURE 2-4. Generalized yields of wells in Puget Sound Study Area.

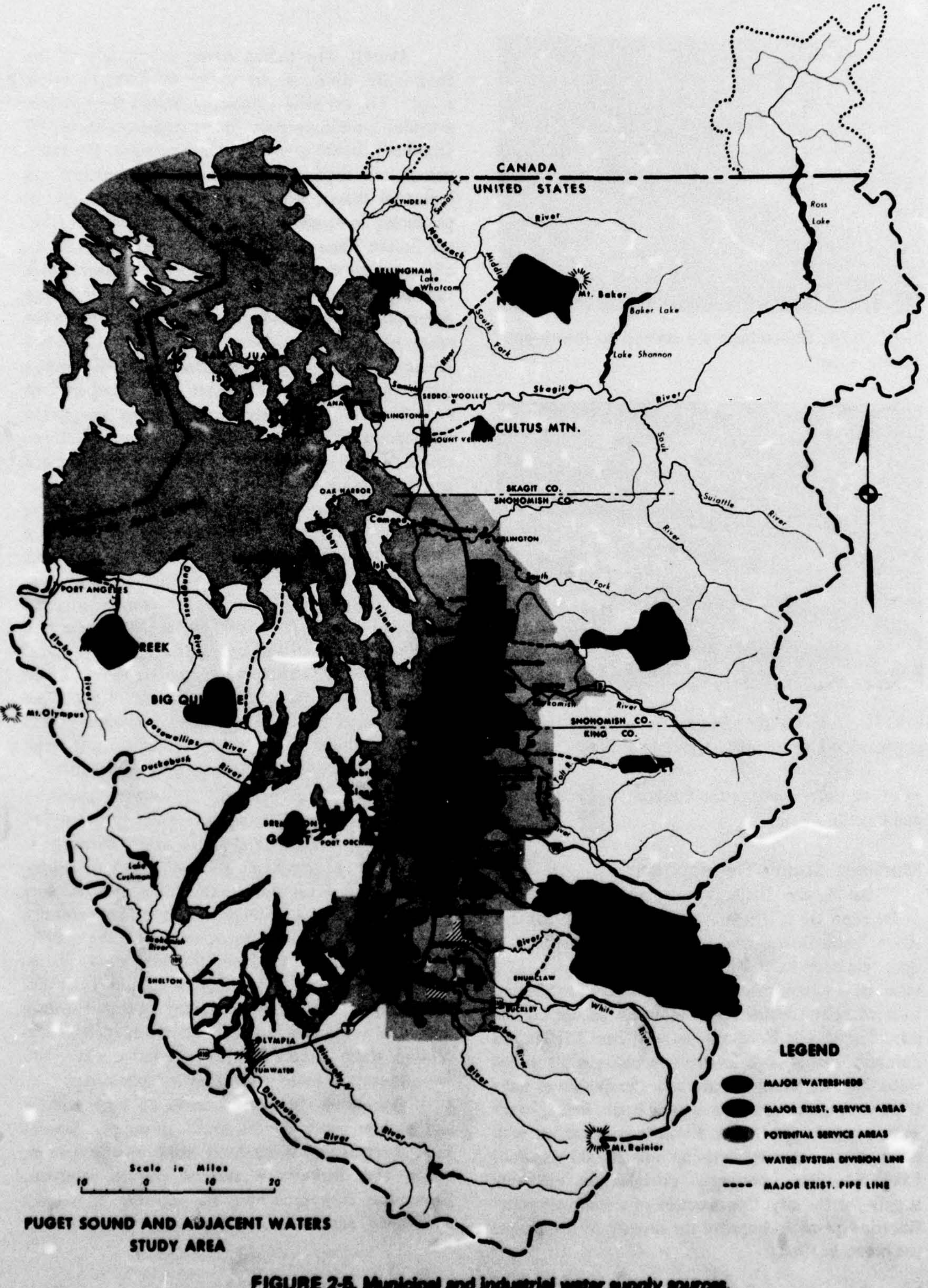


FIGURE 2-5. Municipal and industrial water supply sources.

PHOTO 2-8. Streambeds are cleared to insure good quality water.

PHOTO 2-9. Debris removal is a major task in preparation for reservoir impoundment.

meet the water needs of the Snohomish, Cedar-Green, and Puyallup Basins.

Municipal Supply Development

Bellingham—Bellingham obtains water through a diversion from the Middle Fork of the Nooksack River. Water flows through a system of pipelines and open channels to Lake Whatcom, which acts as a terminal reservoir prior to treatment and distribution to residential, commercial, and industrial users in the city. The Middle Fork originates in glacial fields and normally carries high levels of turbidity. This turbid water has not affected materially the quality of Lake Whatcom, which acts as a settling basin. Bellingham's water right on the Middle Fork, in conjunction with other water naturally draining into 20,000 acre-foot Lake Whatcom, presently provides an adequate supply for the city. Construction of a complete water filtration plant to improve the quality for municipal use began in 1968.

Everett—The Sultan River, a tributary of the Skykomish River, is the source of Everett's water supply. The recently completed Sultan Dam project provides a multi-purpose storage reservoir of 34,500 acre-feet (20,000 acre-feet usable storage). The reservoir is now used as a storage area for municipal and industrial water; plans call for its future use in producing hydroelectric power. Water diverted from the Sultan River is reregulated in Lake Chaplain, an off-stream storage reservoir of 14,000 acre-feet, and is then piped to the city of Everett. The Sultan storage development ensures adequate quantities of water for many years to come. Heretofore, Everett has relied on simple disinfection of its water supply. However, a report made in 1967 by the State Health Department and the U.S. Public Health Service recommended further engineering study of the quality and treatment aspects in view of increasing watershed usage and natural turbidity.

Seattle—In 1901, Seattle developed the Cedar River system, a storage reservoir at Chester Morse Lake with a usable capacity of 23,000 acre-feet and a reregulation reservoir at Lake Youngs, as its primary source of water supply. In recent years Seattle has developed the South Fork of the Tolt River, a tributary of the Snoqualmie River, for additional supply. A storage structure impounding about 60,000 acre-feet of water was developed solely for municipal and industrial needs. This latest development will provide adequate water supplies for Seattle through 1975. Water quality of both systems is excellent.

Tacoma—The primary source of Tacoma's water supply is the Green River. Water is diverted to Tacoma from the river 3 miles below Howard A. Hanson Dam by means of a 42-mile pipeline. During heavy rain, and for short periods, the river becomes turbid. This causes Tacoma to rely on its extensive well field and storage development with the system. Otherwise, the Green River provides good quality water for Tacoma. The city is planning further development of the river, including increased storage and a new pipeline, to meet increased needs. The ground water supply is also of good quality, and development of more peaking wells is planned.

Bremerton—Bremerton relies on both surface and ground water for its source of supply. Several small streams and seven wells make up the system, which also includes a surface storage reservoir. Bremerton is approaching its capacity to supply consumers and is in the process of seeking new

sources. The quality of the water is satisfactory, and disinfection is the only treatment provided.

Port Angeles–Morse Creek, a small stream draining into the Strait of Juan de Fuca, serves as a source of supply for Port Angeles. The system contains no sizeable storage, consisting primarily of a diversion from Morse Creek. The quantity is presently adequate to meet the demands, and the quality is satisfactory most of the time. However, during heavy rain periods, turbidity rises to such a level that in-system storage must be used for short periods in lieu of the diverted water.

Olympia–Olympia gets its water by pumping from McAllister Springs located approximately 8 miles east of the city. The water is soft and of good quality and is satisfactory for the foreseeable future with simple chlorination. Present development supplies 15 mgd, and a total of 30 or more mgd is available.

Multiple-Use Factors

Uncontrolled use of watersheds has raised a potential conflict between recreational development of watersheds and their use as a source of municipal supply. This conflict was brought to the forefront in a publication by the U.S. Forest Service on May 26, 1963, of a "Special Area Multiple Use Plan for the Green River Watershed." As a result of subsequent controversy, the U.S. Public Health Service was requested to conduct a study to "... evaluate the effect of specific management practices and types of uses and users of watershed lands on the quality of water draining from these lands." Subsequent objectives were to "... develop water quality standards to guide multiple-use management practices on forested watersheds supplying water for municipal water supply;" and also develop "... criteria to predict the probable changes in water quality from increased multiple-use of watersheds."

To accomplish the above objectives, the Public Health Service, in the spring of 1966, initiated the Northwest Watershed Project. In consultation with the interested parties, three watersheds (two in the Puget Sound Area and one in the Willamette Basin) were selected for study: the Cedar River, representing a closely controlled and unpopulated area; the Green River, representing a moderately controlled area; and the Clackamas River, representing a moderately populated area with unrestricted access and heavy recreational use.

In addition to quality and quantity data on the water resources, information has been gathered on land use and permanent or temporary residents and persons entering the watershed for work or recreation. Animal populations have been estimated, and some of the smaller creatures have been trapped for bacterial examination.

The 18-month period of field work was completed at the end of September 1967 with removal of all sampling equipment except two virus samplers at the Seattle and Tacoma headworks on the Cedar and Green Rivers. The findings, of this study, were not available when this report was prepared.

WATER RIGHTS

Surface Water

In the State of Washington the basis for most laws governing the appropriation of surface waters is set forth in Chapter 117, Laws of 1917. This chapter now known as the Surface Water Code, firmly established the appropriative doctrine but recognized existing rights of riparian owners and other users that were existing prior to the effective date of the code. To fix the extent of these pre-code rights, an adjudication procedure was also established.

The agency presently responsible for administering the State water code is the Department of Water Resources. This agency had on record as of April 30, 1967, a total of 5,844 surface-water right appropriation records in permit and certificate stages, for the Puget Sound Area. Prime rights in this area allow summer period diversions totaling 33,757.4 mgd of which consumptive diversions account for 2,315.3 mgd, partially consumptive diversions amount to 11,847.8 mgd, and non-consumptive diversions account for the remainder of 19,531.4 mgd. An additional quantity of 212.1 mgd has been allocated under appropriation rights that can be classified as supplemental.

A total of 20 adjudicated surface-water right records in this subregion permit additional prime-right consumptive diversions totaling 372.6 mgd. These rights are all associated with the Dungeness River Decree.

Recorded reservoir-storage rights (permits and certificates) under the appropriative system allow a total quantity of 5,377,240 acre-feet to be retained in storage annually within the Puget Sound Area.

Any person diverting water for any purpose from a stream in the State of Washington is required by the surface water code to secure a permit or certificate for such purpose.

Ground Water

The laws in the State of Washington relating to ground-water appropriation were enacted in 1945 and essentially extend the procedures of the surface-water code to the appropriation of ground waters. Withdrawals for various uses not exceeding 5,000 gallons per day were excluded from the provisions of this Act. To accommodate ground-water users claiming vested rights through developments established prior to 1945, a provision was made for a declaratory period of five years during which such users could acquire a water right through a declaration of their claim. Ground-water rights may also be established through adjudication procedures.

The Department of Water Resources administers ground-water appropriation laws in Washington and as of September 30, 1966, there was a total of 2,575 ground-water right appropriation and declaration records in permit and certificate stages, for the Puget Sound Area. Prime rights in this area allow summer period withdrawals totaling 933 mgd. Nearly all of this quantity, 930 mgd, has a consumptive affect on the resource. The remainder, 3 mgd, is considered to have a partially consumptive affect on the resource. In addition, a total of 39 mgd has been allocated under appropriative rights that can be classified as supplemental.

Table 2-6 is a summary of consumptive surface and ground-water rights in the Puget Sound Area.

TABLE 2-6. Surface and ground water consumptive water rights.

Study basin	Municipal (mgd)[a]	Individual and community domestic (mgd)[a]	Industrial and commercial (mgd)[a]
APPROPRIATIVE RIGHTS			
Nooksack-Sumas	209.9	42.4	28.1
Skagit-Samish	128.7	48.6	24.5
Stillaguamish	14.8	11.5	14.9
Whidbey-Camano	1.3	15.8	1.5
Snohomish	457.6	50.8	75.1
Cedar-Green	115.1	148.5	137.8
Puyallup	587.2	156.0	93.0
Nisqually-Deschutes	34.4	46.2	175.0
West Sound	59.2	116.4	82.6
Elwha-Dungeness	21.2	18.2	123.1
San Juan		2.9	0.3
Subtotal[b]	1,629.4	657.3	755.9
ADJUDICATED RIGHTS			
Elwha-Dungeness	—	374.1	—
Total	1,629.4	1,031.4	755.9

[a]Water right quantities that are common to two or more uses are listed under each applicable category.

[b]Totals for the three categories listed are a portion of the 43,400 mgd appropriated for all uses in the Puget Sound area.

PRESENT AND FUTURE NEEDS

The present water needs of the Area are determined by the urban population and the demands of industrial installations within the service area of the appropriate water department.

Within this Area, in addition to those served by the water department, many independent water districts, companies, and cooperatives may be operating. These suppliers have independent supply sources and distribution systems, or distribute water supplied from a major water department system. The independent installations vary in size from extensive systems serving several thousand persons to privately-owned wells serving a single family residence.

The establishment of reasonable water requirement estimates is governed by population distribution, the climatological region, the geographical area

served, and the adequacy of basic water supplies, the trend of water losses, the trend of per capita consumption, the ratio of residential to industrial users, whether the service is metered or flat-rate, the characteristics of annual peak consecutive days of maximum demand and average monthly demand, and the Washington State fire underwriters' minimum flow requirements. Of these, the principal factor influencing the total annual water use in primarily residential communities is the number of homes.

Water loss is water produced but not accounted for in produced revenue, such as leakage, evaporation, fire protection, line blow-down, and similar unremunerative uses. Per capita consumption normally tends to increase from year to year, primarily because of increasing numbers of water-using appliances in the home. Per capita water use in flat-rate service areas is substantially greater than in metered areas, mostly because of an increased tendency to waste water where the customer's cost does not increase with volume used. Peak demand in these flat-rate areas is more than double that in the metered areas. As a result of these controlling factors, water consumption rates vary over a wide range throughout the Puget Sound Area. Figure 2-6 shows the per capita water use (gpcd) for peak periods of 1 hour to 30 days for a typical large service area. Every water utility should determine its own per capita water use for peak persons in their respective service areas.

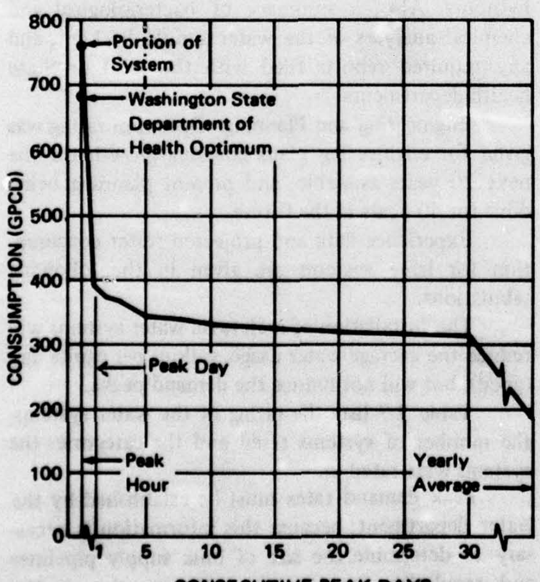


FIGURE 2-6. Seattle planning and design water consumption.

Residential water use is separated into two general categories, household use and sprinkling. A large percentage of the water used within the home is returned to surface water sources via sewers and treatment plants. Water used for sprinkling is largely lost to the atmosphere by evapotranspiration, and may be considered a consumptive use.

Wide variations in delivery pressure have surprisingly little effect on the total water used because, while the higher pressure causes a greater water flow for a given "on" time, most water use is predicated on a volume basis, rather than "on" time. Thus, in high pressure areas, the higher flow rate is compensated for by a shorter flow time to fulfill a given need. Water loss (primarily by leakage) may, however, be considered to increase with an increase in pressure, since flow from a leak is related to the pressure.

Fire protection requirements may determine the size of pipe, amount of storage, and other components of a small system. In larger service areas (over 100 acres), the peak consecutive days of maximum demand becomes constant, and the design and expected demands increase proportionately with the population of the service area. This has led the Washington State Department of Health and the various water departments to express demands of an area on the basis of representative housing densities (service connections per acre) or on average daily per capita use ascertained from records of existing similar systems. Peak consecutive days of maximum demand are then determined from the Health Department criteria or from experience data from existing water departments.

The State Health Department ratings for a firm source water supply and distribution system, criteria are:

Rating	Category	Per capita use (gpd)	Firm water use per service connection (gpm)
1	Optimum	658	1.6*
2	Acceptable	410*	1.0 to 1.6
3	Below standard	165*	0.4 to 1.0
4	Inadequate	165	less than 0.4

*Minimum flow for any peak demand period.

The ratings are based on average domestic service averaging 3.5 persons per residence, a need for heavy lawn sprinkling, and minor industrial demand for the service area. Upward or downward adjustment

of flow rates are made, as applicable, for areas having reduced sprinkling requirements or having heavy industrial water use.

The water facilities inventory rating system (Table 2-7) as developed by the Washington State Department of Health rates water systems in 18 categories. An explanation of these categories is as follows:

Supply Quantity–This category reflects the amount of firm water (available year-round) at the source. To receive an optimum rating, the supply quantity must be 658 gpcd (1.6 gpm per service if the population averages 3.5 people per service). Systems may be able to handle 24-48 hour peaks at a higher rate of supply because of storage facilities near the users.

Surface Sanitary Influence–Only systems with surface supplies were rated in this category. Rating in this category generally parallels AWWA established classes of watersheds. It is a measure of environmental influence on the surface water source (disregarding any chemical treatment that may be done) as evidenced by chemical and bacteriological tests of the raw water.

Ground Sanitary Influence–This is similar to "Surface Sanitary Influence," but applies to ground water sources. Wells and springs should be at least 100 feet from potential pollution sources and the ground water should never come in contact with the environmental atmosphere.

Treatment–This category is a measure of how adequately the raw water is being treated. All surface sources should have disinfection at least. Evidence to support these ratings comes from bacteriological and chemical tests of finished water samples.

Storage Capacity–Ideal storage capacity meets Washington State Fire Underwriters fire flows. This means 30,000 gallons plus 658 gal/capita. This pertains to local storage only which feeds directly into the distribution grid.

Reservoir Covers–All storage of finished water should be covered. If not, outlets should be chlorinated and some provision made for bird control.

Storage Construction–Ideally, storage facilities should be adequate for the next 30 years.

Distribution Pipe Size–Minimum sizes service fire hydrants is 8" (or 6" if mains are looped so water could approach from both sides of the hydrant).

Distribution Grid–All mains 6" and less should be looped. All dead ends should have blow offs. Minimum fire flows should be available at all hydrants.

Distribution Pipe Condition–Pipe is of a permanent type (not wood stave), properly installed, and has an estimated additional life of at least 30 years.

Distribution Meters–The percentage of metered services is indicated here. If only a master meter is in place so that the average and maximum system usage can be determined, a 3 rating was given.

System Reliability–A system is classed as reliable if it is unlikely to go out of service for 24 hours within the next 20 years. Items contributing to this category are auxiliary pumps, power sources, emergency chlorinator, and potential problems such as slide danger.

Cross Connection Control–Ideally, each system would have its own control program approved by the State Health Department.

Bacteriological and Chemical Quality Control–Routine bacteriologic and chemical examinations of samples of water to determine the sanitary quality of the water and its suitability for general use.

Operator Competency–A good system has full time operator(s) who are certified under the voluntary certification program sponsored by the State Health Department.

Records and Data–Each system should have an up-to-date map of the system showing all valves and hydrants. Also, a summary of bacteriological and chemical analyses of the water should be kept, and any required reports filed with the local or State health departments.

Engineering and Planning–Optimum rating was given for engineering plans covering growth for the next 20 years available, and present planning being done for 40 years in the future.

Experience data and projected water consumption for large systems are given in the following tabulations.

The installation of meters on water systems will reduce the average water usage, gallons per capita day (gpcd), but will not reduce the demand peaks.

Table 2-7 lists the rating of the water systems, the number of systems rated and the categories the systems were rated in.

Peak demand rates must be established by the water department, because this information is necessary to determine the size of bulk supply pipelines and regulating (equalizing) reservoirs; this is the

TABLE 2-7. Department of Health ratings of water supply systems. Estimated population served appears in each projected Water Use (1980) Table.

Basin[a]	Nooksack-Sumas		Skagit-Samish		Stillaguamish		Snohomish		Cedar-Green		Puyallup		Nisqually-Deschutes		West Sound		Elwha-Dungeness		San Juan		Whidbey-Camano		Total Puget Sound Area	
Total number of systems	94		52		15		129		340		58		88		273		25		19		137		1230	
No. of sys rated in 5 or more cats.	83		26		13		97		270		42		60		239		22		11		50		913	
Category	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd	Avg rtg	No. sys rtd
Supply quantity	1.2	80	2.3	24	1.4	9	1.3	98	1.9	265	1.1	46	1.4	50	1.8	214	2.7	19	1.3	11	2.0	55	1.6	871
Surface sanitary influence	3.5	24	2.0	11	2.0	2	2.0	33	1.1	51	1.0	17	1.4	19	2.1	70	2.0	9	2.1	3	1.0	1	1.5	240
Ground sanitary influence	1.9	26	2.2	20	1.4	7	1.7	64	1.7	220	1.0	36	1.7	48	1.7	189	1.1	11	1.1	6	1.5	44	1.5	671
Treatment	2.5	77	1.4	25	1.1	10	1.1	93	1.2	262	1.0	40	1.7	51	1.3	213	1.0	16	1.2	10	1.3	44	1.2	841
Storage capacity	1.5	83	2.1	26	1.6	10	1.2	91	1.2	261	1.1	41	1.8	56	1.8	215	1.5	18	2.9	10	3.1	57	1.3	868
Reservoir covers	1.2	68	2.6	25	1.0	11	1.2	89	2.8	242	1.5	40	1.6	55	1.7	221	3.8	1.6	1.3	11	1.0	60	2.2	838
Storage construction	1.1	56	1.0	25	1.3	9	1.1	82	1.1	236	1.0	40	1.3	51	1.4	206	1.1	11	1.1	11	1.5	56	1.1	783
Distribution pipe size	1.3	50	1.6	23	1.8	8	1.2	85	1.2	255	1.3	38	1.2	33	1.5	171	1.1	13	3.3	7	1.9	58	1.3	741
Distribution grid	1.4	39	2.0	21	1.0	1	1.2	65	1.2	250	1.3	37	1.2	16	1.5	115		0	2.2	5	1.4	43	1.3	592
Distribution pipe condition	2.0	47	2.7	24	1.5	6	2.1	82	1.2	254	1.0	37	1.2	40	2.0	169	1.1	12	1.2	8	1.4	59	1.2	738
Distribution meters	2.6	77	1.3	28	2.1	12	2.4	96	1.1	267	1.6	44	1.8	59	1.9	240	2.9	21	3.1	11	1.9	74	1.4	929
System reliability	1.3	21	1.9	22	1.4	3	1.2	73	1.2	258	1.0	37	1.4	34	1.4	131	1.0	4	1.2	5	1.6	51	1.1	639
Cross-connection control	3.0	77	3.0	25	1.0	1	1.0	35	1.1	103	2.1	48	2.2	27	1.5	140	1.9	22	3.0	3	3.0	52	1.5	533
Bacterial quality control	1.3	76	1.9	26	1.0	7	1.2	84	1.2	261	1.0	44	1.3	59	2.0	235	2.0	19	2.2	8	1.8	40	1.3	859
Chemical quality control	1.3	73	1.6	25	1.1	5	1.1	29	1.1	69	1.2	40	1.9	47	2.0	204	2.0	4	2.1	10	1.8	40	1.2	546
Operator competency	2.1	15	2.0	25	1.9	5	2.1	77	2.0	255	1.7	38	2.0	37	2.1	158	2.0	3	2.3	4	2.0	44	2.0	661
Records and data	2.0	10	1.1	21	1.0	1	3.0	64	1.2	256	1.1	37	1.1	16	2.3	124		0	1.8	5	1.5	40	1.3	574
Engineering and planning	1.9	9	1.6	23	1.0	1	2.8	64	1.3	234	1.2	31	1.2	12	1.6	123		0	2.4	4	1.6	39	1.3	540
Avg. of Avgs.[b]	1.9	—	1.9	—	1.4	—	1.4	—	1.4	—	1.2	—	1.5	—	1.8	—	1.9	—	1.9	—	1.9	—	1.4	—

[a] In each basin, a representative number of systems was rated, and the population served appears in each basin chapter, Water Use (1965) Table.

The rating criteria are usually objective, matching a parameter of the system against a numeral scale; for example, "Supply Quantity" is defined to be optimum if it is in excess of 1.6 gallons per minute per connection (service). In each category, the ratings have been matched against the scale: 1.0—Optimum; 2.0—Acceptable; 3.0—Below Standard; 4.0—Inadequate.

[b] All averages are weighted according to population served (sum of permanent and seasonal).

maximum supply requirement of the system. Short-term demands exceeding this rate will be furnished from storage reservoirs constructed within the system. Table 2-8 represents experience data and projected water consumption for four systems within the Study Area.

The design considerations of storage reservoir capacity are correlated with known streamflows and the expected or historical annual distribution of water consumption throughout a 12-month period. For example, see Figure 7-3 of the Cedar-Green Basins. The peaking of this curve may be related to "water deficit" and "soil moisture utilization" periods in evapotranspiration comparisons, (Figures 17 through 20, Appendix III, Hydrology and Natural Environment), if the increase is due to lawn sprinkling. Heavy industrial use is additional to the residential peak.

Present and future needs for Municipal and Industrial Water are presented in detail in the separate basin sections, but are summarized in this section to indicate the improvements needed to obtain adequate facilities for:

1. Supply and Transmission
2. Storage and Distribution

These improvements will be required to supply and distribute the following annual water projected use for the Puget Sound Area (Table 2-9).

TABLE 2-8. Experience data and projected water consumption of four large systems

Seattle Water Department:

Year	Annual Average Per Capita Use (gpd)
1965	125
1980	163*
2000	183*
2020	200*

*Based on 1 gpcd steady increase per year since 1920.

Note: 7-day peak consumption equals 160 percent of annual average; 30-day peak consumption equals 143 percent of annual average.

Source: Forecast of Water Supply and Demand to the Year 2020, City of Seattle Water Department, May 1968.

City of Tacoma Water Division:

Year	Annual Average Per Capita Use (gpd)
1965	225
1980	210*
2000	210*
2020	210*

*Based on constant rate for past consumption demand.

Note: 4-day peak consumption equals 420 mgd (200 percent of annual average); 14-day peak consumption equals 340 mgd (160 percent of annual average.

Source: Forecast of Water Supply and Demand to the Year 2020, City of Tacoma Water Division, May 1966.

King County Water District No. 108:

Demand	Water Usage (gpcd) Small Homes*	Medium-Value Homes**	High-Value Homes***
Annual average	75	75	75
Maximum day	200	260	420
Peak hour	430	560	920

* Lot area of 7,200 to 10,000 sq.ft.; lawn area of 5,500 sq.ft.
** Lot area of 10,000 to 15,000 sq.ft.; lawn area of 8,000 sq.ft.
*** Lot area of 15,000 sq.ft. or more; lawn area of 15,000 sq.ft.

Source: Engineering Report, King County Water District No. 108 (Comprehensive Plan Improvements and Betterments, Revision No. I), April 1965, by Minish, Webb & Associates, Consulting Engineers, Seattle. Based on data from King Co. Water Districts 68, 79, 97, and 108.

King County Water District No. 97:

Demand	Water Usage (gpcd)
Annual average	89
Maximum day	–
Peak hour	620

Note: Predominantly residential area.

Source: Developed from system records.

TABLE 2-9. Projected municipal and industrial annual average water needs, mgd

Basin	1965	1980	2000	2020
Nooksack-Sumas				
Population	77,700	91,600	123,500	168,700
Projected average water usage	73	156	212	293
Skagit-Samish				
Population	55,500	64,200	86,500	118,200
Projected average water usage	28	49	77	116
Stillaguamish				
Population	18,900	30,200	48,500	77,800
Projected average water usage	2	5	9	17
Whidbey-Camano				
Population	20,200	26,900	36,200	49,500
Projected average water usage	4	7	10	15
Snohomish				
Population	190,700	302,700	485,800	780,300
Projected average water usage	165	266	419	540
Cedar-Green				
Population	1,040,220	1,479,000	2,375,700	3,816,300
Projected average water usage	165	354	584	1,122
Puyallup				
Population	345,200	449,200	721,000	1,157,700
Projected average water usage	100	186	329	547
Nisqually-Deschutes				
Population	68,900	107,800	188,000	278,900
Projected average water usage	9	27	52	88
West Sound				
Population	121,900	175,000	274,100	432,700
Projected average water usage	49	93	139	182
Elwha-Dungeness				
Population	28,500	29,800	41,000	56,600
Projected average water usage	64	139	210	271
San Juan Islands				
Population	2,600	2,800	3,700	5,100
Projected average water usage	0.6	0.5	0.8	1.1

Note: All usage figures are rounded to whole numbers, with the exception of San Juan Island figures. All mgd figures are separated into ground and surface water sources in each basin chapter. Present and Future Needs sections in Tables headed Summary of Projected Water Needs.

MEANS TO SATISFY NEEDS

INTRODUCTION

The Puget Sound Area, by the year 2020, will have an average water use of nearly 3,500 mgd of water by 6.9 million persons in a greatly expanded industrial economy. This represents a projected increase of 2,820 mgd over 1965 demands. There is, however, no area-wide shortage of water for present and foreseeable municipal and industrial requirements. There will be serious shortages of water in some basins which will require imaginative planning of future developments for interbasin transfer, greater utilization of ground water resources and perhaps even desalinization.

Because most water systems are presently unable to supply the peak municipal demands of 658 gpcd, considerable expansion and modernization of existing systems will be necessary. Estimates of present peak municipal and industrial capacities for all systems in the Area are 1,660 mgd; by the year 2020, peak demands of 6,490 mgd are anticipated.

Most of the present water supply planning, construction and operation is by local purveyors to satisfy local markets. This eliminates the need for individual users to develop separate and often more costly water sources.

Income from present water rates rarely cover the full cost of planning, developing and maintaining an adequate modern system, particularly in the smaller communities. Therefore, the well-financed and efficiently operated large municipal or utility departments will be increasingly more prominent in supplying future M & I needs because of their ability to meet the needs of a rapid influx of population or industry without rapid rate increases. Small independent or municipal purveyors are expected to merge with expanding municipalities or consolidate into large districts. These developments should result in economies of scale that will benefit the general public and realize the advantages of lowest unit costs.

BASIS FOR PLANNING

Many factors are considered in arriving at the array of alternatives to supply the future M & I water supply needs. Several of the larger purveyors have completed or are in the process of completing long-range plans to assure orderly and timely development to satisfy anticipated needs. Others have employed consulting engineering firms to prepare plans and the State Department of Water Resources has completed comprehensive water studies in Whatcom, Pierce and Kitsap counties. Each of these and other studies were drawn upon in the examination of the various alternative development possibilities. In arriving at cost comparison for alternatives, items are grouped into two general categories, (1) system storage and distribution and (2) supply and transmission—including treatment, where required. Individual alternative costs on the latter are presented in each basin chapter because these costs will vary with the type and location of the source of supply. The former costs, while significant, are essentially the same for each system no matter which source alternative is chosen and are therefore presented in this chapter. A summary on unit cost data used in estimating costs are given in Table 2-13. These data, to facilitate use in cost estimating, are presented in terms of 1,000 people served by the facilities or per mgd of water use. Also included here are discussions of social, administrative and financial factors which are important considerations relevant to all purveyors.

System Storage and Distribution

The distribution system within the purveyors service area consists of a piping grid properly sized to permit supplying the peak hourly demand at adequate pressure. In addition, it must have capacity to supply the necessary water, through a well-planned hydrant system, to provide maximum fire protection. Service connections, including meters, are included as part of the distribution system.

To assist in meeting peak residential demands and fire fighting water requirements, storage equal to one days supply at peak useage is recommended. These reservoirs are located throughout the system either on the surface or underground at higher elevations or they may be elevated tanks or standpipes. In this way adequate pressure can be maintained in the system at all times. In some areas it may also be necessary to install booster pumping stations with adequate standby equipment. As mentioned

previously, the cost of installing and maintaining an optimum storage and distribution system is essentially independent of the source of supply. For this reason distribution cost estimates for all the basins are presented in the Area chapter. Below are given the unit cost data used as a basis for the basin cost estimates presented in Table 2-10, Cost of Distribution System in Place and a computer program to (1) calculate distribution costs for present to 2020, selected urban, suburban, and rural miles of pipe/ 1,000 population (see Table 2-11, Water System Construction and Operation Costs), (2) calculate storage costs for covered reservoirs and elevated storage tanks at an optimum of 658 gpcd for the present to 2020 (Table 2-11), (3) calculate metering costs for the present (if not metered) to 2020 for the known and projected population. Present storage and distribution system conditions are shown in the Present and Future Needs section.

Unit costs were determined by the Washington State Department of Health from consulting engineers and water departments, as follows: (not all project cost data is detailed)

Storage. Unit costs vary by a factor of 30 depending on the size and type of construction of the particular storage facility. For sizes ranging from 0.25 to 2 mg, consulting engineers have estimated $100,000/mg for ground level storage and $250,000/mg for elevated. Tacoma Water Division estimates $20,000/mg for large open ground level reservoirs (30-60 mg) and $40,000/mg for similar covered reservoirs. Large multi-purpose ground level reservoirs (with parking lots, streets, or tennis courts, or even parks on top) conserve space in crowded urban areas and are aesthetically desirable. These have been built for $100,000/mg up to 10 mg, $50,000/mg up to 50 mg, and $20,000/mg for sizes approaching 500 mg.

For Bellingham, consultants estimated $70,000 for a 0.5 mg reservoir ($140,000/mg). Another firm obtained project bids for two steel above ground covered reservoirs: 4 mg for $173,998 plus $25,320 for tank foundation plus $29,000 for painting and a 0.75 mg unit at Forks, Washington, bid at $62,088 plus $12,085 for exterior piping. Adding 30% for engineering and overhead, total unit costs are $74,000/mg and $129,000/mg respectively.

Smaller tanks with auxiliary buildings can cost much more. Tacoma Water Division has estimated $1.50/gallon for complete small storage elevated at 100 feet and $1.00/gallon for large capacities. Planning for Rosario Resort (Orcas Island, San Juan Islands) the cost of a 21,000 gallon ground level steel tank was reported as $12,000 ($570,000/mg). Project for an elevated 0.25 mg tank (golf ball and tee construction) plus an enclosed room at the base cost $90,550 plus $33,260 for tank foundation, floor slab, valve chamber and all concrete work plus 30% for engineering and overhead (total unit cost: $643,000/mg).

These unit costs were developed for Table 2-11 as:

0.25 mg and less

Ground level (open)	
Ground level (covered)	$5,000/mg and up
Elevated (covered)	$1,500,000/mg

0.25-1.0 mg

Ground level (open)	--
Ground level (covered)	$100,000/mg
Elevated (covered)	250,000/mg

30-60 mg

Ground level (open)	$20,000/mg
Ground level (covered)	40,000/mg
Elevated (covered)	--

Distribution System Rule of thumb: one dollar per inch diameter per linear foot. This rule applies to cast iron (CI) or asbestos cement (AC) pipe for sizes from 4 inches to 48 inches with valves and hydrants every 600 feet (installation cost included).

Tacoma Water Division offers the following pertinent data: (including 12% engineering and 15% overhead).

Cost of Mains

Size	Linear Ft.	Hydrants, Valves Linear Ft.
6"	$4.50	$5.50
8"	5.50	7.25
12"	7.50	10.00
16"	13.00	15.10

Figures from a consulting firm (including 30% for engineering and overhead: administration, legal, financing and taxes) are:

Size	Quantity	Cost of mains	Cost of mains hydrants, valves
4"	700'	$ 4.02*	$ 4.82*
6"	30,000 some AC, mostly CI	3.91	4.03
8"	33,000' AC, 8400' CI	5.54	6.75
10"	12,000' AC, 8400' CI	7.10	8.50
12"	31,000' CI	10.02	11.45
16"	30,000' concrete Cyl.	15.66	N.A.

*** High because of the small quantity ordered**

For 6 inch hydrants, average cost (including overhead) was $525 and for 4 inches, $370.

Normal community fire flow systems will have approximately half 6 inches and half 8 inch mains. Using the rule of thumb, the unit cost is $37,000/-mile. State Health Department research determined the following table of population vs. pipe lengths: (see Table 2-10).

	Popula-tion/ acre	Miles distribution pipe/1000 pop.	Cost / 1000 pop.
Urban Area	9.4	3	$110,000
Suburban Area	3.1	9	330,000
Rural Area	1.6	18	660,000

For lower population densities, it is uneconomical to build a fire flow system.

Distribution Meters. Tacoma's Water Division estimates the cost of 5/8 inch meters in 3/4 inch service pipe at $150/meter (installed). One firm, however, has estimated the cost for Bellingham at $75. The Tacoma figure is based on 1968 contract bids, and is considered more reliable.

Supply and Transmission

Source development to meet the needs for M & I water consists of not only construction of surface storage and/or diversion facilities or ground water wells but also bulk transmission pipelines, pumping plants and treatment works. A surface water source alternative will require construction of intake or diversion structure, primary transmission lines, water treatment plants and possibly pumping capability. A ground water alternative will require well construction, pumping facilities and possibly transmission and/or treatment works. Because cost estimates vary widely depending on alternative development possibilities, unit cost data are presented below along with a summary of the cost of implementing the Selected Basin Plans with details on these plans and major alternatives examined presented in individual Basin chapters.

***Unit costs were determined* by the Washington State Department of Health from consulting engineers and municipal water departments, as follows: (not all project cost data is detailed)**

Local Ground Water. Often wells or springs may be located within a mile of the distribution system (sometimes within a few hundred feet). They are much cheaper than surface water initially (little or no transmission main), but have continuing annual pumping energy costs that are reduced or completely avoided with surface supplies.

One engineering firm supplied their ground water cost estimates on "two recent projects involving a spring and a well." Their unit cost planning figure was $60,000/mgd capacity of source (initial well and pump cost only). Another firm gives well costs (drilling only) as $15/ft. for 8 inch diameter (280 feet and 350 feet deep) and $30/ft. for 12 inches (280 feet and 350 feet), but dropping to $21/ft. for 12 inches for a 700 foot well. Tacoma Water Division has estimated $25,000/mgd initial cost for large wells and $50,000/mgd for small wells (180 gpm).

Surface Water–Estimating average cost for a source of surface water is very difficult because transmission line length between the closest satisfactory source and the distribution system can be very long or relatively short, depending on the local situation. In general, a higher initial cost for a long transmission main will mean reduced operation costs for treatment because the water will be of higher

TABLE 2-10. Cost of distribution system in place, minimum fire flows, 6-8 inch mains—valves and hydrants every 600 feet, Washington State Department of Health

Persons per sq. mile	Services per sq. mile for 3.5 persons per service	Persons per acre	Services per acre	Cost per person	Cost per service	Miles Main per 1,000 population
500	143	0.8	0.2	$1,280	$4,500	36.0
1,000	286	1.6	0.4	640	2,250	18.0
1,500	430	2.4	0.7	427	1,480	12.0
2,000	570	3.1	0.9	320	1,120	9.0
2,500	720	3.9	1.1	256	900	7.2
3,000	860	4.7	1.3	214	750	6.0
3,500	1,000	5.5	1.6	183	640	5.2
4,000	1,140	6.3	1.8	160	560	4.5
4,500	1,290	7.0	2.0	142	500	4.0
5,000	1,430	7.0	2.2	120	450	3.6
5,500	1,570	8.6	2.5	116	410	3.3
6,000	1,710	9.4	2.7	107	370	3.0
6,500	1,860	10.1	2.9	99	350	2.8
7,000	2,000	10.9	3.1	92	320	2.6
7,500	2,150	11.7	3.4	86	300	2.4
8,000	2,280	12.5	3.6	80	280	2.3

TABLE 2-11. Water system construction and operation costs, Washington State Department of Health

	Capital Cost $/mgd	Capital Cost $/1,000[1]	Annual[3] Amortized Capital Cost/1,000	Annual Operation $/mgd	Annual Operation $/1,000[1]
Supply and Transmission					
Local Ground Water	$ 60,000[2]	$ 40,000[2]	$ 2,600	(pumping)	(pumping)
Surface Water	130,000	85,000	5,500	(pumping)	(pumping)
Pump Stations	12,000	8,000	500	$10,500	$ 7,000
Treatment					
Filtration	$ 75,000	$ 50,000	$ 3,300	$ 6,000	$ 4,000
Iron Removal (KMnO4)	30,000	20,000	1,300	4,500	3,000
Gas Chlorination (Cl2)	2,000	133	10	400	270
Storage and Distribution					
Reservoirs					
Ground Level (open)	$ 50,000/mg	$ 33,000[4]	$ 2,100[4]	--	--
Ground Level (covered)	100,000/mg	67,000[4]	4,200[4]	--	--
Elevated	250,000/mg	170,000[4]	10,000[4]	--	--
Distribution Pipe (½–6", ½–8")					
Urban (3 mi/1,000 pop.)	-	$110,000	$ 7,000	--	--
Suburban (9 mi/1,000 pop.)	-	330,000	21,000	--	--
Rural (18 mi/1,000 pop.)	-	660,000	42,000	--	--
Distribution Meters	-	45,000[5]	2,900	--	--

1 Cost per 1,000 people served @ 658 gpcd for peak hour.

2 Includes well pumps, controls, power, etc.

3 For 30 years @ 5% interest (.06505).

4 @ 658 gallons/capita/day.

5 @ 3.5 persons/service connection.

quality (remote from populated areas). Although surface water is initially twice as expensive as local ground water, operating costs are lower, especially if the source is tapped at a sufficiently high elevation for gravity feed to the distribution system.

The Tacoma Water Division estimates that additional water from the Green River will cost $15 million for a 90 mgd diversion ($167,000/mgd). The Seattle Water Department has planned a 90 mgd diversion on the North Fork of the Tolt River in 1978 to cost $16 million: (25% for the impounding dam and 75% for transmission main; $178,000/mgd total unit cost). Their 1988 project is an additional 100 mgd diversion from the Cedar River to cost $11 million, 40% for raising the existing Chester Morse Dam and constructing a new diversion dam, and 60% for transmission main (110,000/mgd). A fourth Cedar River pipeline planned for 1998 to supply an additional 100 mgd is expected to cost $6.7 million ($67,000/mgd). This unit cost is lower because there is no need for additional damming facilities for this project. The average unit cost for these four surface water projects, all with relatively long transmission mains, is $130,000/mgd initial cost or about twice the cost of local ground water. For smaller communities, a smaller diversion would tend to raise the unit cost. However, they would probably have shorter transmission mains, which would reduce the costs again.

Pump Stations—One study of 1965 costs across the Nation found that for small systems (0.3-0.5 mgd) the median pumping energy cost was $3.45/1,000 gallons pumped, and for large systems (6-13 mgd) the cost dropped to $1.57/1,000 gallons. It suggested that higher costs for small systems may be due to higher total dynamic head as well as lower pumping efficiencies. For this study, the small system figure is more relevant.

A recent design for Anacortes has three booster pumps totaling 10 mgd capacity with initial cost of $119,000. This figures out to $11,000/mgd unit cost because the pumping head is low and the capacity is large.

In 1967 the Seattle Water Department pumped 9,080 mg for approximately $4.0/1,000 gallons for power. Seattle's costs, however, are abnormally high due to the 500 foot difference in elevation between parts of the city. For this study, $3.8/1,000 gallons will be used for total annual power costs. Also, all gravity supply systems are assumed to pump only to the high service zones continually and to the intermediate service zones on a selected basis.

Chlorination—The major manufacturer of chlorination equipment for the Pacific Northwest has recently quoted the following figures, including scales and tester, for units of up to 100 lbs. chlorine/day, or 12 mgd at 1 mg/l.

Stop-start actuated by pump	$1,100
Automatic feed, variable vacuum control	2,000
Automatic feed, variable vacuum control + meter	2,300

Current cost of chlorine gas is $.13/lb. or assuming an average chlorine demand of 1 mg/l, $400/mgd annually. The low cost is partially due to its local manufacture in Tacoma. Rule of thumb: 8.3 lbs. of chlorine per mg/l chlorine demand per million gallons treated. For small systems (under 0.25 mgd) hypochlorinators are commonly used with the liquid chemical sodium hypochlorite (NaOCl), but are not considered in this Appendix. These unit costs were developed for Table 2-11 as:

	Initial Cost Total	Initial Cost /mgd	Additional Annual Cost/mgd
Gas chlorination (up to 12 mgd)			
Pump-actuated stop-start feed	1,100	90	–
Automatic feed, variable vacuum control	2,000	170	–
Automatic feed, variable vacuum control + meter**	2,300	190	–
Chlorine gas (carried as chemical cost in O & M)	–	–	400

** Unit cost used in this Appendix.

Cost data for installed rapid sand filters:

Size*	Total Capacity	Unit Cost	Total Cost	Cost/mgd
100 ft^2	1.44 mgd	\$250/ft^2	\$ 25,000	\$17,400
1,000	14.4	60	60,000	4,200
10,000	144.0	15	150,000	1,050

*10 gpm/ft.^{2}

Conventional Water Treatment. Bellingham's treatment plant which is now under construction will initially cost \$58,000/mgd. Treatment consists of chemical flocculation for turbidity removal, filtration (high rate sand filters), chlorination, and lime for pH control.

One 1965 study estimates the median unit cost of treatment at \$.40/1000 gallons at 0.15 mgd, \$.30/1000 gallons at 0.4 mgd and \$.20/1000 gallons at 1 mgd. Using \$.30/1000 gallons the cost would be \$110,000/mgd. The same study further offers the data shown at top of page for installed rapid sand filters (filtration equipment only).

Operation and Maintenance are estimated on the basis of a percentage of annual income, late in this chapter. Since each operating water purveyor is assumed to use 70 percent of each annual income dollar on operation and maintenance, the major difference between water systems of equal size would be this annual expenditures for pumping (energy cost) and chemicals. Surface supplies require chlorination and less pumping than ground water supplies which require no chlorination but have greater pumping (energy) costs.

In addition, each project's unit costs were scaled down exponentially as capacity increased from 0.10 mgd to 100 mgd.

Contingency for construction, land purchase, engineering, administration, etc., was assumed as 30 percent of estimated construction costs. There were no special considerations or cost contingencies allotted to flood proofing, unsuitable foundation, power rate variation between basins, transportation costs, tunneling, seismic effects, etc.

Administrative, Financial and Social Factors

As evidenced by costs summarized in Tables 2-12 and 2-13, a substantial investment will be required to correct the existing inadequacies in the public water supply systems, to operate and maintain these systems, and to develop new sources of supply over the next 50 years. Since public water supplies are generally considered to be public utilities, either privately or governmentally operated, development and maintenance costs are usually met by income from sale of the commodity, in this case, water. The ability of purveyors to meet these obligations are influenced by many factors, some of which are discussed below.

Among the administrative factors are the variety of governmental or private entities that may be established to provide water service. The most common practice is to set up a water department as part of city government. Such entities are governed by the municipal officials. Revenue from the sale of water often however, is used to support other municipal functions. This can make it difficult to equate water rates with funds necessary to upgrade and maintain the water system at an optimum level.

Outside municipal boundaries, particularly in low population density areas, other problems are encountered. This type of sparse development makes the construction of a community water supply and distribution system more expensive than in normal urban residential areas, unless annexation to an adjoining city can be accomplished to take advantage of an operating department. Annexation has the benefit of avoiding the construction of separate costly sources of supply. A new administrative organization to serve areas adjacent to cities already in the utility business is not needed.

For those suburban areas remote from an existing municipal system Washington State statutes provide for formation of a variety of administrative entities to provide water service. Water districts are independent agencies completely separate from city and county control. Formation requires a completely new organization capable of administering, operating and maintenance. People served by the district have some control of policies and monthly utility rate charges. While they are practical for large, well-developed areas requiring service, they are not well suited to small, scattered developments, such as those surrounding lakes, recreation/summer home sites, low population density housing subdivisions, etc.

City Local Improvement Districts (LID) have

the advantage of requiring no separate organization for operation and maintenance of utilities (operated by the city) and maintaining a single system rather than constructing independent systems. Disadvantages of a LID are in the differences in water rates inside and outside the cities where property taxes and assessments in areas beyond the city limits are not available to the city, and charges are different, often considerably, for the same water service. There are other legal and political implications, because property taxes in unincorporated areas adjacent to the city are nearly the same as taxes inside the city. The primary determination of property taxes is the school district, not the location inside or outside the city limits.

County Utility Local Improvement Districts (ULID) are authorized under the County Services Act of 1967. These are independent utility systems owned and operated by the county. Previously no authority was granted to counties to form utility districts. As a result, many small State water districts were formed, each with a separate administrative organization. One advantage of the county ULID's is the control over policies and rates by the residents. In addition, a single county can operate, maintain and administer several small districts within its boundaries. A new department within the county to operate the water systems however is required.

Although it is impossible to assess in monetary terms the influence of the administrative organization on the ability of purveyors to adequately serve the M & I needs of the future, it has been assumed for planning purposes efficient entities will be formed to serve through public systems all parts of the Area with a population density of 0.8 persons or more per acre. (Table 2-10).

In addition to the above administrative factors, when a major capital investment is required, such as development of a new source of supply or a major change in the system, it becomes necessary for the purveyor to negotiate a loan or issue bonds to raise the necessary funds. If operating revenue is adequate and/or the bonded indebtedness is sufficiently flexible, such large expenditures are usually met by issuing either general obligation bonds or revenue bonds.

General obligation bonds are repaid by a tax on all properties in the city or county. The financial burden is distributed in proportion to the value of the property served which may not necessarily be related to the benefit received from the water system. Although general obligation bond interest rates are often up to 0.5 percent less than revenue bonds, it is generally more equitable and popular in the State of Washington to utilize revenue bonds for utility systems. This is because revenue bonds are repaid through net earnings of the water/sewer system. The financial burden in this case is distributed over the bonding period so that those portions of the population using the system pay in proportion to their use.

In estimating costs for major improvements it has been assumed that revenue bonds will be issued. Bond service has been based upon the bonds maturing over a thirty-year period and bearing interest at the rate of 5% per annum. In computing bond service, it is assumed that the bonds will mature over the estimated useful life of the facility and have a coverage of 1.4. Water departments or districts have bond coverages as low as 1.15 and as high as 1.6

Bond coverage is by definition the ratio of the net income (after subtracting operation and maintenance costs) to the debt service payments and in this study is 1.5. There are three items of expense to a water utility which are not included in operation and maintenance in order to arrive at the coverage ratio. These are : (1) depreciation which provides for renewals and replacement of the new facilities in a manner consistent with prior policies of the utility, (2) reserves which are funds to provide for betterment and extension of the utility's facilities on a basis comparable to that enjoyed by the entire system; and (3) in-lieu-of-tax payments which are, in accordance with the present statutes of the State of Washington, 3.6% of the gross operating revenues. For purposes of determining the in-lieu-of- tax payment applicable to each plan, 3.6% of the estimated total annual income has been assumed.

Total annual income has been determined from water district and city water department records and annual reports as:

Population Served	Total Annual Income
0 to 40,000	$320/mg
40-000 to 100,000	225/mg
100,000 to250,000	200/mg
250,000 and up	160/mg

Costs may be divided to reflect the two components of annual income as follows.

		% of Total Annual Income
1.	Operation and Maintenance	70%
	Payroll, office, supervision Billing, meter reading general shops, power engineering, utility equipment, Quality assurance and control, etc.	(35% to supply and transmission: 35% to storage and distribution
2.	Bond Coverage	30%
	Depreciation, Reserves, funded deficit, in-lieu of taxes,	(10%)
	Bond Service	(20%)
		100%

It will be noted that an attempt has been made at the conclusion of each of the basin chapters to evaluate the ability of water purveyors in each basin to meet the bond coverage requirements imposed by the needed improvements. These analyses show that financing difficulty may be experienced in the future, particularly in the more densely populated eastern basins. This is however, merely a continuation of past conditions because many purveyors, especially the smaller communities, have historically experienced difficulty arranging adequate financing for major improvements. To provide assistance in meeting present financial obligations, several federal programs have been established. These are briefly summarized below:

The Public Works and Economic Development Act of 1965 (P.L. 89-136)—is administered by the Economic Development Administration of the Department of Commerce. Under its provisions, designated economically depressed areas can obtain direct or supplementary grants for all types of public works projects including public water supply which have employment impact. Direct grants are limited to 50 percent of the project cost; however, supplementary grants in certain depressed areas may increase the grant up to 80 percent. Public Works loans are available for up to 100 percent of the project. In addition, business loans are provided by this Act. These longterm low interest loans are limited to 65 percent of the project cost, or private loans are guaranteed up to 90 percent of the total project cost. The Housing Act of 1968 extended provisions of the original act for one year (1970) and authorized $885 million for water and sewage grants.

The Watershed Protection and Flood Prevention Act (P.L. 566)—is administered by the Soil Conservation Service. In addition to benefits derived from protective land treatment and structural measures, and in addition to making loans and advances to finance the local share of costs (Sec. 8); the Secretary of Agriculture ... "may pay for any storage of water for anticipated future demands or needs for municipal or industrial water included in any reservoir structure constructed or modified under the provisions of this Act not to exceed 30 per centum of the total estimated cost of such reservoir structure where the local organization gives reasonable assurances, and there is evidence, that such demands for the use of such storage will be made within a period of time which will permit repayment of the cost of such water storage within the life of the reservoir structure" ...

The Housing and Urban Development Act (P.L. 89-117). is administered by the newly created Department of Housing and Urban–Development to assure "...sound development of the Nation's communities and metropolitan areas..." Under its provisions, grants for construction of water distribution and treatment facilities are available up to 50 percent of the project cost. Under some circumstances, grants of up to 90 percent can be made. Another provision makes grants of 2/3 of the cost of planning available (¾ in an economically depressed area) for a general area-wide facilities plan. Advance planning loans for individual facilities of up to 100 percent of the cost are also available. The latter need not be repaid if the project is not constructed.

The Consolidated Farmers Home Administration Act of 1961 (P.L. 87-128)—is administered by the Farmers Home Administration of the Department of Agriculture. Under provisions of a 1965 amendment to this legislation, grants of up to 50 percent of the cost of water supply facilities can be made to communities with under 5,500 population. In addition, the Act provides for development loans or loan insurance and grants up to 100 percent to aid in comprehensive area-wide planning for water supply and sewage disposal projects.

The above programs are not however, universally applicable nor may they be adequately funded to provide the financial assistance required to implement the improvements envisioned here. As comprehensive financial analysis of the capability of water utilities to provide an optimum system is in order to determine the need for additional planning and

construction grant or loan programs, by the State and/or Federal Governments.

There has been no attempt in estimating costs to include social or non-market costs and benefits or bring them into the area of human needs vs. the value of water. One such factor currently of immediate concern in the Puget Sound Area is that of controlled access watersheds. In this controversy information on the public health implications and social goals as well as economic cost variations are important in our present society. People are willing to pay for basic needs and protection from injury, disease and death, as well as for aesthetics. Multiple use decisions must take into account the net benefit in determining the feasibility of a project.

Recreation is now and probably will continue to be one of the major water and related land uses. On the other hand, the domestic water user seeks a water source free of pollution and as close to its pristine state as possible. If compromise of these divergent desires is mandatory for any existing single-purpose reservoir or watershed, stringent management techniques to control quality deterioration from recreation and other uses will be necessary.

Also, water treatment facilities commensurate with the degree of quality degradation must be installed to protect the consumers' health. The question then reduces to the economic feasibility of controls and treatment and methods of financing the cost of facilities and management.

An evaluation of both political and economic ramifications comes into play in this situation. The cost of the additional treatment must be borne by a limited number of water consumers while recreation benefits pass to a smaller, widely spread, separate group. It has been suggested that additional costs of public water supplies for equipment, operation and maintenance resulting from recreation use should be assigned to the recreation function. Where the water consumers constitute a different group from those receiving the recreational value, some method of reimbursement for increased treatment costs should be made.

Where a true recreational deficiency has not been proven, domestic-purpose reservoirs should be held in reserve and restricted to domestic and compatible uses, such as hydroelectric power generation and controlled logging. Only when it becomes necessary to satisfy a clearly defined recreational need should they be developed for recreational use, and then only if such development, including water treatment, is economically justified and financially feasible.

AREA WATER PLAN

For the purpose of this report, area plans are described in terms of the following water requirements:

1965 or Immediate Requirements
Year 1980 Requirements
Year 2000 Requirements
Year 2020 or Ultimate Requirements

It is not considered that implementation of the plan will be developed in these major increments. It is anticipated that the water plan will grow in relative increments in accordance with the requirements of each water service area. The major increments of the plan shown are based on projected population and land use determination. It is not possible to accurately anticipate all possible variations in land use developments which may require extension or modification of the generalized plan presented herein. It is anticipated that each basin plan will be modified in detail at the time that the general plan for each water service area is developed and that it will be further refined as facilities are constructed. Basically a basin plan presents an orderly and logical basic plan for water supply and distribution which fulfills the criteria previously discussed herein.

This section of the report presents the major features of fulfilling the M & I water source and transmission requirements of an increasingly urbanized and industrialized Puget Sound Area envisioned for the period from 1965 to 2020 for:

1. The Selected Area Plan, Table 2-12.
2. The Alternative Area Plan, Table 2-13.

The source plan for each basin is shown in detail in its chapter. The distribution system improvements, which remain the same irrespective of source development have been presented earlier. The Selected Area Plan and the Alternative Area Plan can be compared and sumarized as follows:

Quantity and quality on the whole, are adequate for all requirements contingent upon individual basins being able to import water from basins having adequate supplies, except for the San Juan Islands.

The San Juan Island future water supply appears to be assured only with a feasible scheme of water development reclamation or reuse. Brackish water desalinization, recharge of known aquifers and

further location and testing additional ground water reservoirs for augmenting meager surface water supplies offers some possibilities.

Area water needs will increase from an annual average of 660 mgd in 1965 to 2,992 in 2020. Basins, such as the Cedar-Green and the Puyallup, which presently depend upon imported water, will draw upon these sources to a much greater extent, as their population and industry increase.

Inter-basin transfers will increase in number and size as urban demands proceed upward. From an engineering standpoint, there are few insoluble problems, and the joint development of a river or ground water basin can confer advantages much greater than could be obtained by the aggregate of a number of individual schemes.

The primary source of water from the present to the year 2020 is shown as surface water, ground water, or imported water. Only the Puyallup and Cedar-Green Basins and the San Juan and Whidbey-Camano Islands must import water because their increasing needs are greater than the potential supply. The San Juan and Whidbey-Camano Islands lack adequate supplies of water for any need except rural-individual and a few small community supplies. The Puyallup, Cedar-Green and Whidbey-Camano Basins presently use water imported from other basins.

Accomplishments are a comparison of the difference between the peak mgd at optimum requirements and the present (1965) or projected (1980-2020) peak in the Water Use Tables for each basin. The magnitude of this number shows how the consecutively occurring peaks of domestic users, plus the maximum industrial-demand month structures a system's design, as the average annual demand does not. This value increases from 1965 to 2020 and represents, numerically, the same conditions as the upturn in graphs of:

1. Projected Population Growth (example: Figure 7-4)

2. Relative Production Growth (example: Figure 7-5) after the year 2000.

Residual represents the capacity necessary to supply peak uses over the annual average use in Table 2-9. This number shows that once the water supply systems are brought up to optimum rating (after 1965), all peak demands for the Area as a whole are approximately twice the annual average. Regionally this is true, but examination of the Nooksack-Sumas, the Stillaguamish and other basins indicates that each basin by itself is a much different circumstance.

Costs for system expansions are determined from unit cost data presented in Table 2-11, approximately $2.3 billion to the year 2020 for both the Selected Area Plan and the Alternative Area Plan. The majority of funding is required for storage and distribution, and net supply source and transmission development, as any water system of more than a very nominal size can demonstrate.

1965	20% of $55 million income for bond service	$11 million
	Bond service required for facilities	4 million*
1980	20% of $94 million income for bond service	$19 million
	Bond service required for facilities–million 1967 dollars	12 million*
2000	20% of $156 million income for bond service	31 million
	Bond service required for facilities–million 1967 dollars	23 million*
2020	20% of $216 million income for bond service	43 million
	Bond service required for facilities–million 1967 dollars	38 million*

*Costs from Table 2-13, 1967 dollars.

By 1985 income which can conceivably be applied to service bonds will not be adequate to provide the optimum systems due to cost increases. By 2020 bond service to construct facilities will be more than three times the increased income from 1965 to 2020.

Bonding costs and income available are examined in the individual basins Means to Satisfy Needs Sections.

The Selected Area Water Supply Plan is an extension of existing major M & I water supply departments and utilities plans to supply developing areas and the many small water districts, companies and cooperatives within their service or transmission areas by annexation or direct bulk delivery. Surface water from within the basin will be the main supply for seven of the basins. Four of the basins will use or depend upon imported water from adjoining basins.

Five basins will be surface water; four, imported water; and two will remain on ground water supplies.

Supply and transmission costs for these basin supplies will be about $464 million. This financial outlay will result in a number of storage and reservoir projects, in addition to a much smaller percentage of ground water development, to supply an annual average need of 2,992 mgd.

The Alternative Area Water Supply Plan—is the second most feasible and economical plan for the major supply departments. Both alternatives are based on the assumption that major purveyors will:

1. Annex adjacent areas
2. Direct retail sale of water to smaller systems
3. Become the major purveyor in a county service or regional system. Smaller departments will purchase or otherwise receive water from the larger purveyor. Nonetheless many will find it cheaper or desirable to develop their own source in any form of surface or ground water.

The difference in cost for the Puget Sound Area between the selected and alternative plan to the year 2020 is approximately $15 million, the alternative plan being more expensive. This increased cost is due to more municipalities using surface water, which is higher unit cost to begin with (Table 2-11) and which also, in most instances, requires treatment.

It must be noted that both the selected and alternative plans will supply the Annual Average and Optimum (or Peak) Requirements (see Tables 2-12 and 2-13).

Municipal and Industrial Water Supplies have been projected and developed on the basis that where water is available the projected needs can be met with their accompanying estimated costs. Additional functions and water needs are presented in other appendices and have equal consideration for use of water with municipal and industrial supplies.

Municipal and Industrial Supplies do not have a predominant or preferred right over other needs such as irrigation, fish and wildlife, etc. A more equalitarian treatment than "water is available and can be taken as desired" is considered in the appendix on comprehensive plan formulation.

TABLE 2-12. Selected area plan for municipal and industrial water supply

Plan Level	Need (mgd) Annual Average	Need (mgd) Peak or Optimum	Plan (1. Primary Source 2. Secondary Source 3. Tertiary Source) Surface Water	Plan Import. Sur. Wtr.	Plan Grd. Wat.	Accomplish-ments[a] (mgd) Supply and Transm.	Accomplish-ments[a] (mgd) Storage and Distrib.	Residuals[b] (mgd) (Addl. Wtr. Nec. for Meeting Peaks)	Million 1967 Dollars Amortized Capital Cost Supply and Transm.	Storage and Distrib.	Total	Total Annual Income
1	2	3	4	5	6	7	8	9	10	11	12	13
Nooksack-Sumas												
Exist.		77 mgd										
1965	73	101	1	None	2	24	24	29	6.47	3.59	10.06	8.644
1980	156	200	1	None	2	99	99	44	12.67	5.09	17.76	13.861
2000	211	271	1	None	2	71	71	69	9.08	10.69	19.77	28.122
2020	293	371	1	None	2	100	100	80	5.00	14.97	19.97	28.266
									33.22	34.34	67.56	
Skagit-Samish												
Exist.		44 mgd										
1965	28	53	1	None	2	9	9	26	1.21	3.48	4.69	3.154
1980	49	79	1	None	2	26	26	31	5.44	2.92	8.36	5.462
2000	77	118	1	None	2	39	39	43	8.13	6.69	14.82	8.644
2020	116	176	1	None	2	58	58	62	11.29	11.46	22.75	11.590
									26.07	24.55	50.62	
Stillaguamish												
Exist.		7 mgd										
1965	2	8	None	None	1	1	1	6	0.10	0.61	0.71	0.188
1980	5	14	None	None	1	6	6	11	0.46	1.94	2.40	0.421
2000	9	28	None	None	1	14	14	21	0.86	4.47	5.33	0.865
2020	17	50	None	None	1	22	22	37	1.15	6.77	7.92	1.518
									2.57	13.79	16.36	
Snohomish												
Exist.		210 mgd										
1965	164	247	1	None	2	37	37	86	4.12	6.90	11.02	12.074
1980	266	406	1	None	2	159	159	143	18.75	37.49	56.24	19.199
2000	419	647	1	None	2	241	241	232	19.57	65.88	85.45	30.587
2020	540	894	1	None	2	247	247	358	20.57	111.30	131.87	32.032
									3.01	221.57	284.58	
Cedar-Green												
Exist.		407 mgd										
1965	165	738	1	2	3	331	331	573	9.09	40.54	49.63	13.549
1980	354	1,067	1	2	3	329	329	696	8.90	159.57	168.47	23.713
2000	584	1,804	2	1	3	737	737	1,082	43.52	326.00	369.52	39.483
2020	1,122	3,139	2	1	3	1,335	1,335	1,687	100.55	524.77	625.32	72.646
									162.06	1,050.88	1,212.94	
Puyallup												
Exist.		125 mgd										
1965	100	293	3	1	2	168	168	192	10.10	13.57	23.61	7.357
1980	186	403	3	1	2	110	110	218	33.61	38.19	71.80	10.032
2000	329	667	3	1	2	264	264	337	36.52	99.08	135.60	17.913
2020	547	1,060	3	1	2	393	393	513	59.61	159.54	219.15	29.636
									139.84	310.38	442.91	

[a] Accomplishments: The existing or projected optimum peak mgd minus the optimum peak mgd for the next successive plan level.

[b] *Residual: Optimum peak mgd minus the annual average for the plan level.*

Note: Individual system water requirements and development costs are shown in their respective basins' "Means to Satisfy Needs" sections.

TABLE 2-12. Selected area plan for municipal and industrial water supply (Cont'd)

	Need (mgd)		Plan 1. Primary Source 2. Secondary Source 3. Tertiary Source			Accomplish-ments[a] (mgd)		Residuals[b] (mgd)	Million 1967 Dollars			
									Amortized Capital Cost			
Plan Level	Annual Average	Peak or Optimum	Surface Water	Import. Sur. Wtr.	Grd. Wat.	Supply and Transm.	Storage and Distrib.	(Addl. Wtr. Nec. for Meeting Peaks)	Supply and Transm.	Storage and Distrib.	Total	Total Annual Income
1	2	3	4	5	6	7	8	9	10	11	12	13
Nisqually-Deschutes												
Exist.		20 mgd										
1965	9	28	2	None	1	8	8	22	0.27	2.10	2.37	.736
1980	27	59	2	None	1	7	7	25	1.78	2.02	3.80	2.364
2000	52	113	2	None	1	17	17	35	3.09	9.55	12.64	4.648
2020	88	183	2	None	1	26	26	50	3.80	14.16	19.13	7.498
									8.94	27.83		
West Sound												
Exist.		54 mgd										
1965	49	115	1	None	2	51	51	66	4.32	7.87	12.19	3.790
1980	93	168	1	None	2	53	53	77	6.60	16.49	23.09	6.774
2000	137	256	1	None	2	88	88	120	9.45	35.83	45.28	9.678
2020	182	354	1	None	2	98	98	237	10.16	48.61	58.77	14.496
									30.53	108.80	170.56	
Elwha-Dungeness												
Exist.		77 mgd										
1965	64	77	1	None	2			13	0.02	2.50	2.52	5.417
1980	139	164	1	None	2	87	87	25	0.78	0.48	1.26	11.542
2000	210	243	1	None	2	79	79	35	1.28	3.44	4.72	15.677
2020	271	348	1	None	2	75	75	49	0.64	5.01	5.65	20.209
									2.72	11.43	14.15	
San Juan												
Exist.		5 mgd										
1965	0.6	17	1	None	2		12	16		0.59	0.59	
1980	0.5	25	2	1	2		8	24		0.08	0.08	
2000	0.8	41	2	1	2		16	40		0.32	0.32	
2020	1.1	73	2	1	2		32	72		0.50	0.50	
										1.49	1.49	
Whidbey-Camano												
Exist.		5 mgd										
1965	4	13	3	2	1	8	8	9	0.77	1.41	2.18	0.421
1980	7	18	3	1	2	5	5	12	0.34	2.46	2.80	0.749
2000	10	25	3	1	2	7	7	15	5.15	3.28	8.43	1.168
2020	15	34	3	1	2	9	9	20	1.89	4.65	6.54	1.635
									8.15	11.80	19.95	
Total Area												
Exist.		1,031 mgd										
1965	660	1,690	1	2	3	659	671	1,038	36.5	83.2	119.7	66.330
1980	1,283	2,603	1	2	3	889	897	1,360	89.3	266.7	356.0	94.117
2000	2,042	4,213	1	2	3	1,573	1,589	2,031	136.7	565.2	701.9	156.785
2020	3,192	6,652	1	2	3	2,395	2,427	3,105	214.7	901.7	1,116.4	217.528
										1,816.8	2,294.0	

[a] Accomplishments: The existing or projected optimum peak mgd minus the optimum peak mgd for the next successive plan level.

[b] Residual: Optimum peak mgd minus the annual average for the plan level.

Note: Individual system water requirements and development costs are shown in their respective basins' "Means to Satisfy Needs" sections.

TABLE 2-13. Alternative area plan for municipal and industrial water supply

Plan Level	Need (mgd) Annual Average	Need (mgd) Peak or Optimum	Plan: 1. Primary Source 2. Secondary Source 3. Tertiary Source — Surface Water	Import. Sur. Wtr.	Grd. Wat.	Accomplishments[a] (mgd) Supply and Transm.	Accomplishments[a] (mgd) Storage and Distrib.	Residuals[b] (mgd) (Addl. Wtr. Nec. for Meeting Peaks)	Million 1967 Dollars — Amortized Capital Cost: Supply and Transm.	Storage and Distrib.	Total	Total Annual Income
1	2	3	4	5	6	7	8	9	10	11	12	13
Nooksack-Sumas												
Exist.		77 mgd										
1985	73	101	1	None	2	24	24	29	4.58	3.59	8.17	8.644
1990	156	200	1	None	2	99	99	44	13.21	5.09	18.30	13.861
2000	211	271	1	None	2	71	71	69	9.55	10.69	20.24	28.122
2020	293	371	1	None	2	100	100	80	4.56	14.97	19.53	26.266
									31.90	34.34	66.24	
Skagit-Samish												
Exist.		44 mgd										
1985	28	53	1	None	2	9	9	26	1.21	3.48	4.69	3.154
1990	49	79	2	None	1	26	26	31	3.27	2.92	6.19	5.462
2000	77	118	2	None	1	39	39	43	5.95	6.69	12.64	8.644
2020	116	176	2	None	1	58	58	62	8.70	11.46	20.16	11.590
									19.13	24.55	43.68	
Stillaguamish												
Exist.		7 mgd										
1985	2	8	1	None	2	1	1	6	0.10	0.61	0.71	0.188
1990	5	14	2	None	1	6	6	11	2.09	1.94	4.03	0.421
2000	9	28	2	None	1	14	14	21	2.66	4.47	7.13	0.865
2020	17	50	2	None	1	22	22	37	3.51	6.77	10.28	1.518
									8.36	13.79	22.15	
Snohomish												
Exist.		210 mgd										
1985	161	247	1	None	2	37	37	86	4.30	6.90	11.20	12.074
1990	263	406	1	None	2	159	159	143	18.57	37.49	56.06	19.199
2000	419	647	1	None	2	241	241	232	24.73	65.88	90.61	30.587
2020	540	894	1	None	2	247	247	358	31.19	111.30	142.49	32.032
									68.79	221.57	300.36	
Cedar-Green												
Exist.		407 mgd										
1985	165	738	1	2	3	331	331	573	18.94	49.54	54.48	13.549
1990	364	1,067	2	1	3	329	329	696	21.70	159.57	181.27	23.713
2000	584	1,804	2	1	3	737	737	1,082	26.92	326.00	352.92	39.483
2020	1,122	3,139	2	1	3	1,336	1,336	1,687	100.56	524.77	625.32	72.646
									167.63	1,050.88	1,213.99	
Puyallup												
Exist.		125 mgd										
1985	101	293	3	2	1	168	168	192	6.66	13.57	20.23	7.357
1990	185	403	3	1	2	110	110	218	21.73	38.19	60.02	10.032
2000	329	667	3	1	2	284	284	337	44.38	99.08	143.46	17.913
2020	547	1,060	3	1	2	383	383	513	66.05	159.54	225.59	29.636
									138.82	310.38	449.20	

[a] Accomplishments: The existing or projected optimum peak mgd minus the optimum peak mgd for the next successive plan level.

[b] Residual: Optimum peak mgd minus the annual average for the plan level.

Note: Individual system water requirements and development costs are shown in their respective basins' "Means to Satisfy Needs" sections.

TABLE 2-13. Alternative area plan for municipal and industrial water supply (Cont'd)

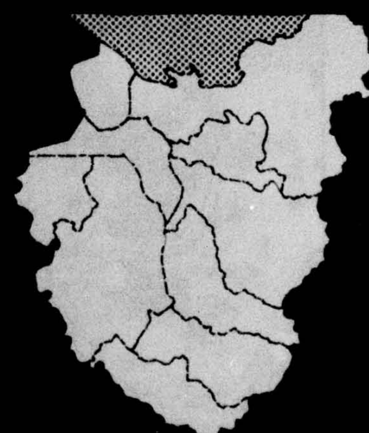
	Need (mgd)		Plan: 1. Primary Source, 2. Secondary Source, 3. Tertiary Source			Accomplishments[a] (mgd)		Residuals[b] (mgd)	Million 1967 Dollars			
									Amortized Capital Cost			
Plan Level	Annual Average	Peak or Optimum	Surface Water	Import. Sur. Wtr.	Grd. Wat.	Supply and Transm.	Storage and Distrib.	(Addl. Wtr. Nec. for Meeting Peaks)	Supply and Transm.	Storage and Distrib.	Total	Total Annual Income
1	2	3	4	5	6	7	8	9	10	11	12	13
Nisqually-Deschutes												
Exist.		20 mgd										
1985	9	28	1	None	2	8	8	22	4.18	2.10	6.28	.584
1980	27	59	1	None	2	7	7	25	4.18	2.02	6.20	2.283
2000	52	113	1	None	2	17	17	35	4.18	9.55	13.73	3.980
2020	88	183	1	None	2	26	26	50	4.18	14.16	18.34	6.862
									16.72	27.83	43.00	
West Sound												
Exist.		54 mgd										
1985	49	115	2	3	1	51	51	66	4.84	7.87	12.71	3.790
1980	93	168	2	1	3	53	53	77	14.36	16.49	30.85	6.774
2000	137	256	2	1	3	88	88	120	3.87	35.83	39.70	9.678
2020	182	364	2	1	3	98	98	237	4.59	48.61	53.20	14.496
									27.66	108.80	136.46	
Elwha-Dungeness												
Exist.		77 mgd										
1985	64	77	1	None	2			13	0.02	2.50	2.52	5.417
1980	139	164	1	None	2	87	87	25	2.85	0.48	3.33	11.542
2000	210	243	1	None	2	79	79	35	0.86	3.44	4.30	15.677
2020	271	348	1	None	2	75	75	49	1.69	5.01	6.70	20.209
									5.42	11.43	16.85	
San Juan												
Exist.		5 mgd										
1985	0.6	17	1	None	1		12	16		0.59	0.59	
1980	0.5	25	2	1	2		8	24		0.08	0.08	
2000	0.8	41	2	1	2		16	40		0.32	0.32	
2020	1.1	73	2	1	2		32	72		0.50	0.50	
										1.49	1.49	
Whidbey-Camano												
Exist.		5 mgd										
1985	4	13	3	2	1	8	8	9	0.60	1.41	2.01	0.421
1980	7	18	3	1	2	5	5	12	2.74	2.46	5.20	0.749
2000	10	25	3	1	2	7	7	15	1.45	3.28	4.73	1.168
2020	15	34	3	1	2	9	9	20	1.77	4.65	6.42	1.636
									6.56	11.80	18.36	
Total Area												
Exist.		1,031 mgd										
1985	680	1,690	1	2	3	659	871	1,038	45.4	83.2	128.6	85.178
1980	1,283	2,603	1	2	3	889	897	1,350	104.7	266.7	371.4	94.016
2000	2,042	4,213	1	2	3	1,573	1,589	2,031	124.6	565.2	689.8	196.127
2020	2,992	6,652	1	2	3	2,395	2,427	3,105	226.8	901.7	1,128.5	216.892
									492.7	1,816.8	2,309.5	

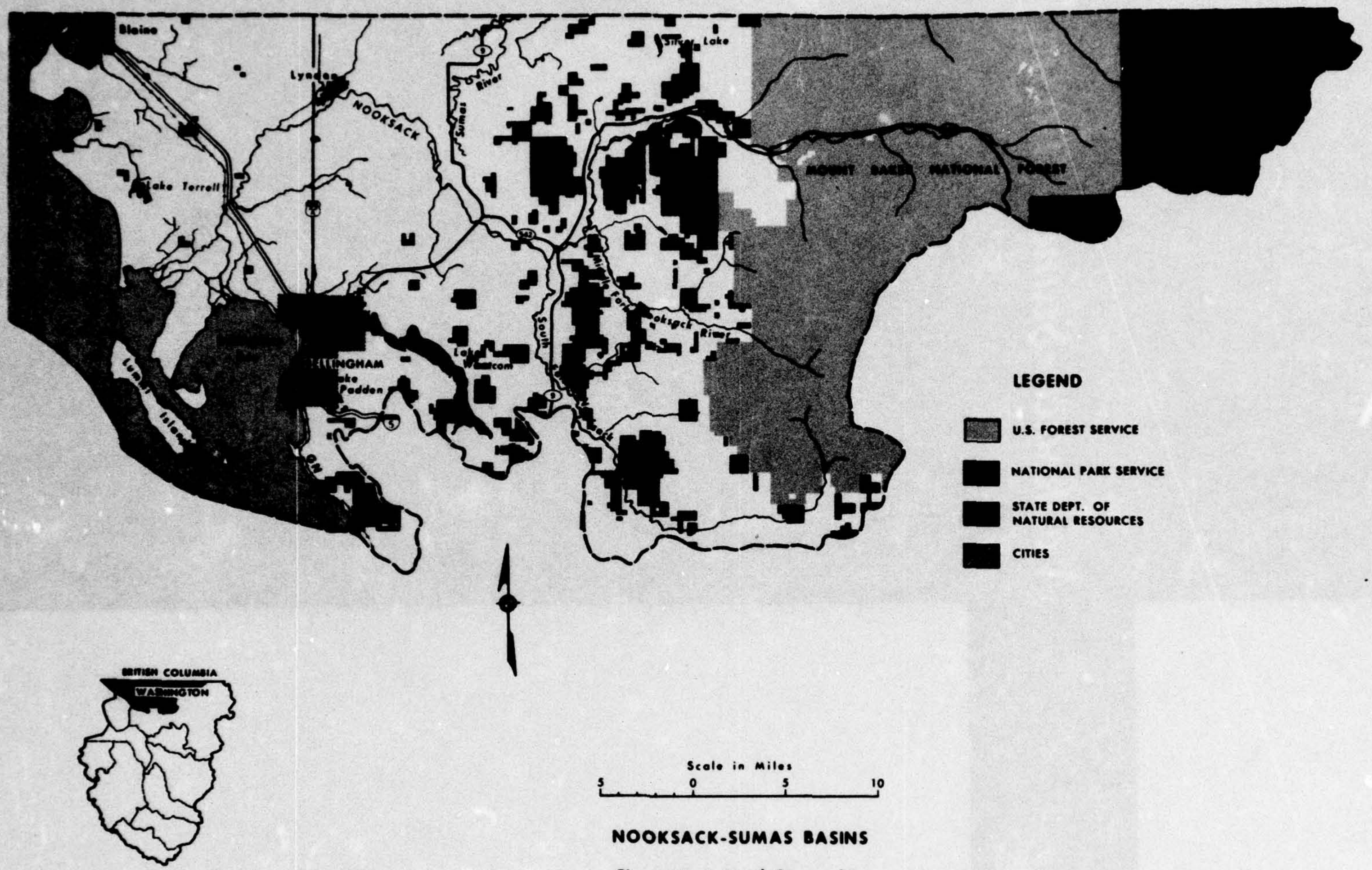
[a] Accomplishments: The existing or projected optimum peak mgd minus the optimum peak mgd for the next successive plan level.

[b] Residual: Optimum peak mgd minus the annual average for the plan level.

Note: Individual system water requirements and development costs are shown in their respective basins' "Means to Satisfy Needs" sections.

Nooksack-Sumas Basins





NOOKSACK-SUMAS BASINS

Figure 3–1 Land Ownership

NOOKSACK-SUMAS BASINS

INTRODUCTION

The Nooksack-Sumas Basins, Figure 3-1, bounded on the east by the western slopes of the Cascade Mountain Range and on the west by the Strait of Georgia, is located in the northern corner of the Puget Sound Area. Occupying about 1,628 square miles of land in Whatcom County, the Basins encompass the expanding urban-industrial center of Bellingham, an important deep-water port. Principal industries in the Basins are dairying, forest products, oil refining, and base metal reduction.

A considerable increase in population and industry, supported by a continuing increase in activity and tonnage handled at the port of Bellingham, is projected for the Basins. The demand for municipal and industrial water supplies is expected to increase commensurate with this growth. Projections indicate that population will increase 216 percent by the year 2020, production growth is expected to triple, and total water requirements are expected to reach 293 million gallons per day, more than four times the present water needs of about 72 million gallons per day. Surface and ground water supplies now adequately meet municipal and industrial needs, except in some rural areas and new industrial park developments. Presently developed water sources, however, will be unable to meet projected future demands, and will require additional facilities and larger systems.

GEOGRAPHY

The Nooksack-Sumas Basins have contrasting geographical features. The eastern portions, extending into the Cascade Mountain Range, are remote, heavily forested mountainous areas that include the peaks of Mount Baker (10,778 feet) and Mount Shuksan (9,127 feet), both continuously snowclad. From the mountains to the Strait of Georgia, the Basins consist of rolling hills, numerous streams and lakes, and hummocky glacial plateaus connected by gentle slopes to richly fertile lowlands of the broad river valleys. Of the 1,628 square miles that comprise the Basins, 1,256 square miles consist of land and inland waters.

The largest and most important stream system in the Basins is the Nooksack River and its major tributaries, the North, South, and Middle Forks. The tributaries of the Nooksack head in the Mount Baker-Shuksan area of the Cascade Range and converge near the town of Deming, around which the Nooksack flood plains make up much of the fertile lowlands. From Deming, the river winds through 37 miles of twisting channels to its outlet in Bellingham Bay. The Nooksack drains about 826 square miles, of which 49 square miles are in Canada. Between the Nooksack River and the Canadian Border lie the headwaters of the Chilliwack and Sumas rivers, which flow northward to the Fraser River in British Columbia. The Chilliwack drains 174 square miles in Washington and the Sumas drains some of the lowlands in the northwestern part of the Basins.

Practically all the surface water storage in the Basins is contained in natural lakes, Lake Whatcom being the largest, and in snowfields and glaciers on Mount Baker and Mount Shuksan.

CLIMATE

The Nooksack-Sumas Basins experience a typically mid-latitude, West Coast marine-type climate. The Basins have mild but rainy winters and cool summers, with a mean temperature of about 10°C (50°F). Winter temperatures average 4.4°C (40°F), and summer temperatures average 16.6°C (62°F). The temperature seldom reaches 32°C (90°F) in the summertime. Rainfall is light in summer, increases in fall, reaches a peak in winter, and then decreases in spring. The heaviest rainfall, about 100 inches annually, occurs on the summit and slopes of Mount Baker. Throughout the Basins, 80 percent of the rain falls in the winter months, and heavy snowfall on the Cascade Mountain Range provides storage water to assure streamflow in the Basins throughout the summer.

POPULATION

The estimated 1967 population is about 77,300, over half of which is urban. The principal towns and their estimated population are Bellingham with 36,500, Lynden with 2,850, Blaine with 1,775,

Ferndale with 1,850, Sumas with 674, and Everson with 625.

ECONOMY

The economy of the Nooksack-Sumas Basins is based on dairying, forest products, oil refining, canning, pulp and paper products, and reduction of primary metals, such as aluminum. In addition, the deep water ports of Bellingham and Blaine are major Northwest shipping centers.

Only a few years ago, the Basins economy was based almost completely on timber and agricultural products. Although these are still major industries, other important water-using industries, including an oil refinery, a pulp and paper mill, and an aluminum reduction plant, have recently moved into the Basins. This industrial diversification has stimulated population growth and economic expansion in the Basins. The reclamation of tidelands at Bellingham for industrial use will add further to this expansion.

In addition, the Nooksack-Sumas Basins is experiencing an increase in tourist trade from both local and Canadian residents. The scenic areas, particularly Mount Baker National Forest, attract several hundred-thousand persons annually for recreational activities such as hunting, fishing, hiking, riding, skiing, and camping.

LAND USE

Mountainous forests and alpine country (Photo 3-1) in the eastern part of the Basins, most of which is Federally owned, accounts for about 75 percent of total land use. The lowland areas, once completely covered by dense forests of conifers, were cleared and converted to farm land at the beginning of this century, and have since developed into one of the major dairy centers of Washington State. Thus, most of the agricultural land on the flood plains and in the river valleys (about 140,000 acres) is now used for permanent pasture and hay crops to support the dairy industry. Urbanized areas, mostly in and around Bellingham and Ferndale, occupy approximately 20,000 acres. Table 3-1 summarizes general land use in the Basins.

PHOTO 3-1. Alpine meadows and mountains dominate the eastern portion of the Basins.

TABLE 3-1. General land use

Type	Acres
Forestland	609,000
Cropland	137,000
Rangeland	12,000
Other land (high, barren)	13,000
Urban buildup	21,000
Inland water	12,000
Total land and inland water	804.000

Source: Appendix III, Hydrology.

PRESENT STATUS

WATER USE

Surface and ground water supplies now adequately meet municipal and industrial needs, except in some rural areas. Certain rural-individual supplies are inadequate in either quality or quantity. Ground water is presently scarce in the Lake Terrell uplands, surrounding Ferndale Industrial Park. Any substantial growth in this area will most likely result in replacement of the existing small wells with a large surface water system.

Present municipal, industrial, and rural-individual water use in the Basins averages 72.7 million gallons per day (Table 3-2), of which

industries use 83 percent and the remainder is tapped from municipal and rural-individual outlets by approximately 77,700 persons. At present, approximately 94 water systems (Table 2-7) serve a total of more than 62,000 people, about 80 percent of the total Basins population. The systems vary widely in size, but about 50 of them serve less than 200 persons each. The present status of water use in the Basins is summarized in Table 3-2.

Municipal

Daily municipal water use in the Basins, from both surface and ground sources, averages about 11.2 mgd. Of this, about 8.9 mgd is supplied to some 40,000 users in the Bellingham area for a per capita usage of nearly 223 gpd. The remaining 19,400 municipal users are supplied approximately 1.9 mgd from several small distribution systems for a per capita usage of 98 gpd. Average per capita usage for

TABLE 3-2. Water use (1965)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Surface water usage (mgd) Maximum daily	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Ground water usage (mgd) Maximum daily
MUNICIPAL USE							
Bellingham	40,000	8.90	12.50	36.20	—	—	—
Blaine	4,200	—	—	—	0.47	0.55	0.65
Sumas	3,200	—	—	—	0.39	0.72	1.05
Lynden	2,600	0.40	0.80	1.20	—	—	—
Ferndale	1,600	—	—	—	0.25	0.37	0.50
Everson	600	—	—	—	0.11	0.25	0.16
Rural community systems	7,200	—	—	—	0.54	0.85	1.16
Subtotal	59,400[c]	9.30	13.30	38.40	1.90	2.60	3.52
RURAL-INDIVIDUAL USE	18,300	0.10[a]	0.20	0.30	0.90[a]	1.30	1.80
INDUSTRIAL USE							
Municipally supplied:							
Bellingham							
Food and kindred		0.96	1.36	1.64	—	—	—
Paper and allied		46.40	50.50	54.00	—	—	—
Other		0.75	0.80	0.84	—	—	—
Ferndale							
Food and kindred		—	—	—	0.32	0.85	1.40
Lynden							
Food and kindred		0.21	0.31	0.41	—	—	—
Self-supplied							
Food and kindred		0.76	1.00	1.22	0.23	0.35	0.60
Primary metals		8.00	8.00	8.00	—	—	—
Petroleum		2.80	2.80	2.80	—	—	—
Subtotal		59.88	64.76	68.91	0.55	1.20	2.00
Total[b]	77,700	69.3	78.3	95.6	3.40	5.10	7.30

[a] Based on assumed 55 gpcd and 90 percent of rural population to be served by ground water.

[b] Figures are rounded.

[c] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

the entire Basins is slightly more than 230 gpd. The rather high per capita usage in the Bellingham area seems to be accounted for by the lack of a domestic service metering system.

Although Bellingham, largest water supplier in the Basins, provides more than 80 percent of the water used by municipal consumers in the Basins, this quantity represents only about 17 percent of the total amount of water used in the Bellingham area. The remainder is supplied to industrial users. Average daily water use for Bellingham from 1942 through 1966 is plotted in Figure 3-2. Average monthly demand profiles for municipal use, Georgia Pacific Mills, and the total system is shown in Figure 3-3.

Industrial

The largest industrial user in the Basins is the Georgia-Pacific Pulp and Board Mill which is served from the Bellingham municipal system, about 65% of the total system supply. Water use for the mills is shown in Figure 3-2. This plant operates five facilities: (1) a calcium-base sulfite mill with a capacity of 527 tons of pulp per day; (2) a board mill with a capacity of about 40 tons of paper board per day; (3) a waste liquor recovery plant which produces marketable quantities of alcohol and dried liquor solids; (4) a tissue mill with a capacity of 190 tons per day; and (5) a new chlorine plant. Of the 46 mgd of water used by the entire plant, the estimated amount of water

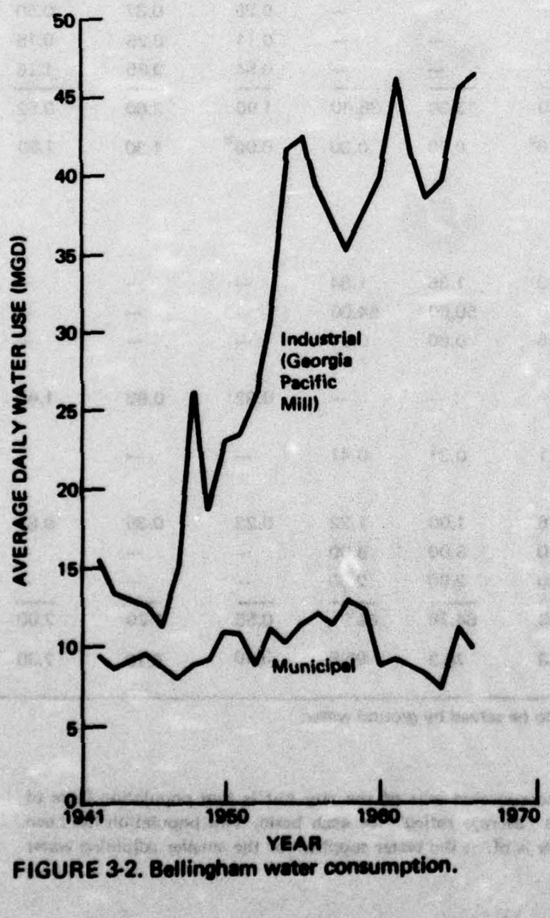


FIGURE 3-2. Bellingham water consumption.

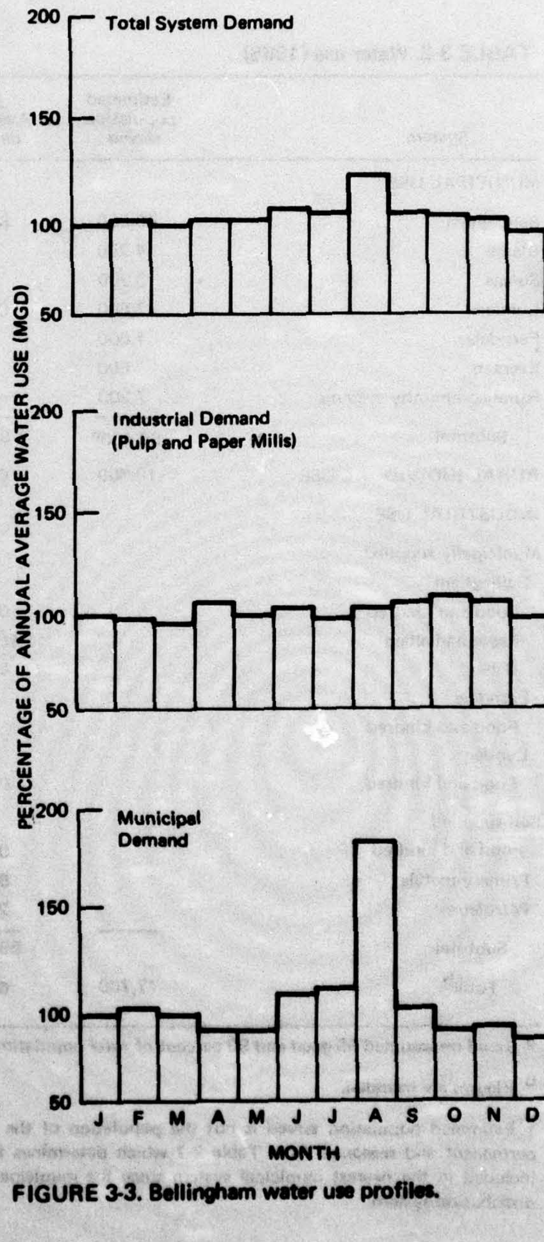


FIGURE 3-3. Bellingham water use profiles.

used by four of the facilities is summarized in Table 3-3.

TABLE 3-3. Georgia Pacific mill water use

	Production capacity (tons/day)	Average daily use (mgd)	Use per unit production
Sulfite pulp plant	527	37.6	71.4
Paper board plant	40	1.4	35.0
Paper plant	190	7.0	36.8

The Intalco Aluminum Reduction plant west of Ferndale operates two potlines with a capacity of 153,000 short tons per year. The plant uses an average of 7 mgd, or 16,700 gal/ton. The plant has capacity for the addition of a third potline.

The Mobil Oil refinery, also located west of Ferndale, refines crude oil received from Canada. Production capacity is about 37,000 barrels per day and water use averages 2 mgd, which indicates a unit water use of 54 gallons per barrel.

Fish, fruit, vegetable, and similar processing industries in Bellingham, Lynden, Ferndale, and Everson use an average of 2.48 mgd during their seasonal production.

Rural-Individual

About 18,300 widely scattered rural-individual consumers (Photo 3-2) use approximately 0.10 mgd of surface water and 0.90 mgd of ground water. These figures are based on the assumption that ground water is used by 90 percent of the rural population and that per capita use is 55 gpd. At present, numerous small wells serve the rural population.

PHOTO 3-2. Small wells constitute the major sources of domestic water for rural and industrial sources.

WATER SUPPLIES

As previously stated, the total daily water consumption in the Nooksack-Sumas Basins averages about 72.7 mgd. Of this total, surface water supplies 69.3 mgd, and ground water supplies the remaining 3.4 mgd. The main sources of water are the Nooksack River and its major tributaries, the North, South, and Middle Forks, and Lake Whatcom. Other sources include numerous creeks, streams, drilled wells, and springs.

Municipal

Two cities, Bellingham and Lynden, obtain their water from the Nooksack River. The remaining municipal systems use ground-water supplies.

Bellingham—Bellingham relied primarily on Lake Whatcom as a source of water prior to completion of the diversion from the Middle Nooksack River in April 1962 (Photo 3-3). Water from the Middle Fork is now diverted through a 10-mile pipeline into Mirror Lake, from where it flows down Anderson Creek into Lake Whatcom. Present capacity of the pipeline, 95 cfs (60 mgd) satisfies average daily system demand.

Operation of the system is directed toward holding the level of Lake Whatcom nearly constant at elevation 314 feet. The lake level is required by court order to be maintained at an elevation not to exceed 314.94, which provides an active storage capacity of about 20,000 acre-feet. Both inflow from the Middle Fork diversion and outflow from the lake are varied to maintain this level. Total capacity of Lake What-

PHOTO 3-3. Bellingham diverts water from the Middle Fork of the Nooksack River for municipal and industrial use.

com at elevation 315 is 765,000 acre-feet. All domestic water in Bellingham is processed through a filtration plant.

Lynden—Lynden diverts its water supply from the Nooksack River at Lynden. Treatment prior to distribution includes filtration and disinfection. Three relatively small food processing industries are served by the system.

Ferndale—Ferndale obtains its water supply from five drilled wells. Water is provided without treatment to an estimated 1,600 people. Approximately 85 percent of the 700 services in the town are metered. One major vegetable freezing plant is also served by this system.

Many small cooperative water systems have been formed in areas where ground water is deep and expensive to reach on an individual basis, or where iron concentrations in the shallow ground-water supply are sufficiently high to be objectionable. These rural systems serve much of the area surrounding Lynden and west of Ferndale.

Industrial

Whatcom County PUD No. 1 provides industrial water to the Intalco Aluminum Company from the Nooksack River at Ferndale. The water is classified prior to delivery.

All large industrial water supplies are obtained from publicly-owned systems, except that for the Mobil Oil Company refinery near Ferndale. This company diverts an average of 2 mgd (maximum of 2.7 mgd) from the Nooksack River, filtering the water prior to use.

Rural-Individual

An estimated 4,460 rural-individual water systems within the Basins serve 18,300 people. About 90 percent of these systems use ground water as a source of supply.

WATER RIGHTS

The Nooksack-Sumas Basins have a total of 927 recorded water-rights; of these, 374 are surface and 533 are ground (1966-1967). Municipal use accounts for most of the appropriated surface water, and as presently authorized under prime rights, a maximum of 199 mgd can be diverted for this purpose. The city of Bellingham has rights under two filings to divert most of this quantity. The largest of these, for 162 mgd on the Middle Fork of the Nooksack River, has been partially perfected, and at present the city is actually diverting about 66 mgd. No diversion works have been constructed at this time in conjunction with a surface water permit which allows the city of Bellingham to develop 32 mgd of the flow from the South Fork of the Nooksack River. The city of Lynden holds a certificate to divert up to 3 mgd from the main stem of the Nooksack River for municipal purposes. Individual and community domestic systems account for 30 mgd of the appropriated water in this area.

Approximately 87 percent of the developed ground water in this Basin is used for irrigation. A total of 118 mgd has been appropriated for this use. Individual and community domestic supplies account for a total of 12 mgd. This figure does not reflect most single domestic wells which are not required under present laws to have recorded water rights. Withdrawals of up to 11 mgd are permitted for municipal supplies, with the cities of Sumas, Everson, and Ferndale drawing 3 mgd, 2 mgd, and 0 mgd, respectively. Table 3-4 shows water rights in the Nooksack-Sumas Basins.

TABLE 3-4. Municipal and industrial water rights

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	199.0	29.9	25.7
Ground water	10.9	12.5	2.4
Total [a]	209.9	42.4	28.1

[a] About 100 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

SURFACE WATER

Quantity Available

Streams—The largest and most important surface water resource in the Basins is the Nooksack River and its three major forks. The North Fork is actually the main stem of the river, and is joined by the Middle and South Forks near the town of Deming.

The Nooksack River has two high runoff periods each year: one in the fall or winter coinciding with the period of maximum precipitation, and one in the spring during the period of snowpack melt-off.

A stream discharge station located near Lynden has been used to measure annual runoff of the Nooksack from a drainage area of about 648 square miles.

Annual discharge for the Nooksack River, as measured near Lynden, averaged 3,700 cfs from 1944 through 1965. A maximum flow of 46,200 cfs was recorded at this station in February 1951, and a minimum flow of 595 cfs was recorded in November 1952.

A lowflow frequency analysis computed by the USGS from data collected at the Lynden station during the 18-year period from April 1946 to March 1964 revealed 7-day and 30-day lowflow that can be expected to occur at this station at intervals of 5, 10, and 20 years. This data is summarized in Table 3-5.

TABLE 3-5. Lowflow frequency

Discharge station	Recurrence interval (years)	7-day low-flow (cfs)	30-day low-flow (cfs)
Nooksack River near Lynden	5	900	1,110
	10	760	1,000
	20	660	880

Stream gaging records on the Middle Fork, Bellingham's source of water supply, are intermittent, covering only a few years. However, based on available data that have been correlated with that of the Nooksack River, average annual discharge is estimated to be 450 cfs and the minimum 30-day lowflow expected to occur once in 20 years is estimated to be 180 cfs.

Dams and Impoundments—There are two impoundments in the Nooksack-Sumas Basins, one at Lake Whatcom and the Nooksack Falls power plant at Excelsior. Lake Whatcom supplies municipal water to Bellingham, as discussed in the following paragraph; the Nooksack Falls impoundment is used only for power generation.

Lakes—Practically all surface water storage in the Basins is contained in natural lakes, including Lake Whatcom, Lake Padden, and Lake Terrell, which have surface areas of 5,003 acres, 152 acres, and 700 acres (maximum), respectively. Lake Whatcom, largest lake in the Basins, acts as a reservoir for the Bellingham Municipal Water System. The lake provides an active storage capacity of 20,000 acre-feet, but has a total capacity, at elevation 315.00, of 765,000 acre-feet.

Quality

Water quality data have been obtained by the U.S. Geological Survey and the Washington Water Pollution Control Commission for Lake Whatcom near Bellingham; Nooksack River at Deming; and for the Nooksack River at Ferndale. The period of record for these stations is shown in Table 3-6. About 30 small streams have been sampled once and analysis made for only a few parameters. Water quality of Lake Whatcom has been measured by the Institute for Freshwater Studies at Western Washington State College.

In 1965, the U.S. Forest Service established a water quality station on the Middle Fork of the Nooksack River about one mile above the diversion that supplies water for Bellingham. Samples collected, primarily during the summer months, were analyzed for suspended sediment and bacteria in addition to measurement of water temperature at the time of collection.

The quality of water in Lake Whatcom has been intensely studied by the Institute for Freshwater Studies at Western Washington State College since April of 1962 to determine the effect of diverting water from the Middle Fork of the Nooksack River into the lake and to establish a basis for predicting probable changes in quality of the lake water as a result of the diversion. However, a definite trend of water quality has not been established. Although water entering the lake from the Nooksack River is more turbid than the lake water, it drops to the lower level of the lake shortly after entering and rapidly mixes and dilutes.

Physical–The color of Nooksack River waters at Ferndale is variable, but exhibits generally higher values than the Skagit River waters. Color values range from 0 to 25 units.

The turbidity of the Nooksack River is high when compared to most streams in the Puget Sound Area, primarily because of the substantial quantities of glacial melt water in the river. Turbidity of the Nooksack River at Ferndale ranges from 5 JTU (Jackson Turbidity Units) to a maximum of 700 JTU.

Temperatures of the river at Ferndale ranged from 2.0°C (3.6°F) to 17.5°C (63°F). The mean temperature is 9.1°C (48°F). Temperatures at the Deming Station are in the same approximate range, but average 16.5°C (61°F) in the summer and 2.5°C (45°F) in the winter. Water temperature of Lake Whatcom is considerably warmer at the surface than the water temperatures at the Nooksack stations. A low of 3.5°C (38°F) and a high of 21.4°C (70°F) were recorded. The warmer lake temperatures account for the turbid Middle Fork waters going to the bottom of the lake where the sediment precipitates without increasing the turbidity of Lake Whatcom.

Chemical–The chemical quality of surface waters in the Nooksack-Sumas Basins is generally excellent. The water in all basin streams is generally soft, with normal hardness values of 60 mg/l or less. Hardness values of more than 100 mg/l are unusual. The total concentration of dissolved solids in the surface waters in the area rarely exceeds 100 mg/l. A maximum dissolved solids content of 77 mg/l was revealed in samples collected monthly over a 5-year period from the Nooksack River at Ferndale. Analysis of samples taken from small tributary streams around Lynden and Ferndale revealed about twice the concentration of dissolved solids recorded in the Nooksack River and nitrate levels ranged from 0.8 to 3.8 mg/l, as compared to a mean of 0.8 mg/l recorded for the Nooksack at Ferndale.

The Nooksack River and its major tributaries are fast-running streams, and dissolved oxygen (DO) concentrations are usually near saturation throughout their length. DO concentrations on the lower Nooksack River at Ferndale range from a minimum of 5.1 mg/l to a maximum of 13.6 mg/l, based on records collected from October 1961 through May 1966. Further upstream, at Lawrence, DO concentrations range from a minimum of 9.8 mg/l to 12.9 mg/l. Minimum oxygen saturation values of 88 percent and 89 percent were recorded at the Lawrence and Ferndale stations, respectively. Most samples were nearly 100 percent saturated. Table 3-6 lists chemical quality data gathered from several area streams.

From 1963 through 1966, samples were collected weekly by the Institute for Freshwater Studies at Western Washington State College at four stations on Lake Whatcom and were analyzed for dissolved oxygen (DO), pH, and coliform bacteria. Water temperatures were recorded at the time samples were taken. A maximum mean monthly surface water temperature of 20.2°C (68°F) was recorded during August 1963. Maximum and minimum mean monthly surface DO concentrations of

TABLE 3-6. Surface water quality

			MG/L												MG/L									MG/L		MG/L		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
										WHATCOM LAKE NEAR BELLINGHAM									OCTOBER 1961 THROUGH PRESENT								
Maximum	...	52	7.2	1.9	6.0	0.8	24	0	8.8	5.8	0.2	1.1	61	0.03	...	6.7	0.16	0.02	7.1	10	15	21.4	13.0	122	22	4	930
Mean	...	32	5.3	1.5	3.3	0.5	22	0	5.1	2.6	0.1	0.6	56	0.01	...	1.9	0.07	0.02	...	...	...	12.3	10.7	102	19	2	184
Minimum	...	28	4.8	0.7	2.9	0.2	17	0	4.4	1.5	0.0	0.1	54	0.00	...	0.6	0.02	0.01	6.6	0	0	3.5	8.6	90	18	0	0
Number	...	25	25	25	25	25	25	24	25	25	24	25	24	12	...	25	12	4	24	24	12	27	27	27	25	24	27
										NOOKSACK RIVER AT DEMING									DECEMBER 1965 TO SEPTEMBER 1966								
Maximum	9,130	68	12.0	3.5	2.8	0.9	46	0	14.0	1.6	0.2	1.0	103	0.21	...	9.8	7.70	0.06	7.8	50	330	16.4	13.4	137	44	10	24,000
Mean	...	49	8.9	2.3	1.6	0.5	32	0	8.0	0.7	0.1	0.4	73	0.02	...	7.4	1.09	0.01	...	...	...	9.3	11.2	100	32	5	727
Minimum	3,800	35	6.0	1.2	0.9	0.1	22	0	4.2	0.0	0.0	0.0	49	0.00	...	4.7	0.01	0.00	6.9	0	5	2.4	9.8	88	22	2	0
Number	11	40	40	40	40	40	40	14	40	40	40	40	40	37	...	40	37	9	40	40	20	40	41	40	40	40	41
										NOOKSACK RIVER AT FERNDALE									JULY 1959 THROUGH PRESENT								
Maximum	...	77	13.0	4.9	4.2	1.0	53	0	15.0	4.2	0.3	2.5	128	0.06	...	11.0	7.50	0.02	7.7	25	700	17.5	13.6	121	53	10	24,000
Mean	...	56	9.5	2.9	2.4	0.6	36	0	9.2	1.9	0.1	0.8	85	0.02	...	8.1	1.16	0.01	...	...	...	9.1	11.1	99	36	6	2,488
Minimum	...	32	5.0	1.4	1.2	0.2	22	0	5.4	0.2	0.0	0.1	51	0.00	...	5.1	0.08	0.00	6.8	5	5	2.0	5.1	45	22	2	36
Number	...	57	57	57	57	57	57	33	57	57	57	57	57	46	...	57	43	7	57	61	46	60	60	59	57	57	60

11.8 ppm and 8.1 ppm were recorded, respectively, in April 1965 and August 1965. Bottom DO concentrations were considerably lower, particularly in the extreme western sector of the lake. Mean monthly bottom DO concentrations from this sector of the lake of 0.0 ppm were recorded during August, September, and October of 1966.

Bacteriological—Bacteriological quality data gathered from the Nooksack River indicate a general trend of increase in coliform concentration from the headwaters to the mouth. The higher concentrations of coliform bacteria usually occur during the summer months in stream reaches below the more populated areas.

Data obtained at Lawrence showed that in the upper reaches of the Nooksack River, bacterial levels normally ranged from 36 to 91 MPN, though occasional higher values were recorded. In the Middle Fork of the Nooksack River, bacterial levels normally ranged from 0 to 105 MPN. Bacterial concentrations in samples taken at Ferndale ranged from 36 to 4,600 MPN with a recorded maximum MPN of 24,000.

During 1966, mean surface concentrations of coliform bacteria in samples taken by the Institute for Freshwater Studies at Western Washington State College from the western part of Lake Whatcom ranged from 1 to 49 MPN, and bottom concentrations ranged from 0 to 61 MPN. Both surface and bottom concentrations of coliform bacteria were found to be highest in the western part of the lake.

Lake Whatcom bacteriological water quality data have also been obtained by the city of Bellingham and the Washington Water Pollution Control Commission. High coliform concentrations during the winter months were found by both agencies. City data for the period 1961 through 1963 revealed maximum concentrations of up to 700 MPN for all three winters. Washington Water Pollution Control Commission data for 1964 through 1966 showed maximums of 930 MPN for February and October 1965.

GROUND WATER

Quantity Available

Ground water supplies are plentiful in much of the Nooksack-Sumas Basins. The major water-bearing materials in the Basins are the river and glacier-deposited silts, sands and gravels which extend throughout most of the western lowlands. Natural recharge to these ground water reservoirs is by direct precipitation.

High ground-water yields are found primarily in the western lowland section in the vicinity of Ferndale, Custer, Lynden, Everson, and Sumas. Shallow wells in these areas readily produce 100 to 200 gpm, with only two to three feet of drawdown. Yields of 500 gpm or more could be obtained with five to ten feet of drawdown.

Areas of moderate yield include the delta lowland of the Nooksack and Lummi Rivers south of Ferndale, the area west of Custer to Blaine, the lower Custer trough, the lower fringes of the upland areas east of Ferndale, and the lower portions of the North, Middle, and South Fork valleys of the Nooksack River.

Quality

The ground waters are relatively low in dissolved solids, although they have a somewhat higher mineral content than the surface waters. They are generally of good chemical quality.

Ground waters may be classed as soft to slightly hard. In many ground waters, hardness is only 60-80 mg/l, while others are as high as 175 mg/l, with the average hardness being about 150 mg/l.

Iron frequently exceeds the U.S. Public Health Service standard for iron and manganese combined. Taste and odor problems caused by these impurities are frequent in the Nooksack and Sumas River lowlands. The city of Lynden treats water from the sediment-laden Nooksack River rather than use the abundant supplies of ground water. Table 3-7 lists the results of analysis of samples taken from numerous ground water sources.

TABLE 3-7. Ground water quality

Owner	Location code[a]	Depth (ft)	Date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulphate (So_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids[b]	Hardness ($CaCO_3$)	Specific conductance (umho)[c]	pH
				MG/L																	
U.S. Government (USFS spring)	37/8-25E1s	——	10/27/54	54	23	0.02	8.4	3.9	6.4	2.4	27	0	25.0	4.0	0.2	0.3	—	88	32	113	7.3
Neptune Beach	38/1-4D	144	3/1/60	46	23	0.07	31.0	22.0	20.0	—	218	0	–	14.0	0.3	—	—	226	167	415	8.1
Emma Bodtke	38/5-2Q2	18	3/2/60	—	—	0.01	10.0	3.6	—	—	37	0	—	—	—	—	—	82	40	136	6.4
Tony Fresia	38/5-29D	16	3/2/60	—	—	3.4	16.0	21.0	3.6	—	180	0	—	3.5	0.1	—	—	162	128	255	7.4
City of Ferndale	39/2-19M	161	12/17/59	45	21	0.06	45.0	23.0	132.0	7.6	289	6	24.0	162.0	6.2	0.0	0.31	556	206	1,030	8.4
			5/18/60	55	—	—	—	—	—	—	303	0	—	—	—	—	—	—	215	1,000	8.1
City of Ferndale	39/2-19Q3	157	3/1/60	50	—	0.56	42.0	19.0	116.0	—	291	0	—	121.0	—	—	—	480	184	811	8.2
C.V. Wilder (Larabee spring)	39/2-36D1s	—	4/7/49	—	19	0.01	23.0	10.0	18.0	3.0	124	0	8.5	22.0	0.2	2.0	—	171	98	296	7.3
Emma MacMillen	39/3-10J2	92	3/1/60	—	—	0.07	13.0	2.1	—	—	39	0	—	—	—	—	—	85	41	122	6.5
Meridian Water Assoc.	39/3-18D2	24	3/1/60	—	22	0.28	16.0	7.8	12.0	—	47	0	12.0	14.0	0.2	32.0	—	132	72	218	6.9
Otto Sehrt	39/4-32P	179	3/2/60	—	—	0.28	17.0	11.0	—	—	470	0	—	8.0	—	0.0	—	450	86	706	8.1
Don Healand	39/4-34C	100	3/2/60	—	32	0.12	27.0	9.9	41.0	—	235	0	—	6.5	—	0.0	—	238	108	372	8.0
Joe Zender	39/5-3F1	44	3/2/60	—	—	0.06	26.0	4.6	—	—	105	0	—	—	—	—	—	118	84	188	8.2
City of Blaine (well 5)	40/1-3F	53	12/17/59	48	25	0.00	12.0	5.2	5.1	1.3	70	0	4.4	2.5	0.1	0.1	0.25	93	51	129	7.5
			5/18/60	46	—	—	—	—	—	—	70	0	—	—	—	—	—	—	61	128	7.4
City of Blaine (spring)	40/1-3M1s	—	4/7/49	—	24	0.01	12.0	6.5	5.8	2.0	78	0	6.7	3.3	0.2	0.1	—	90	57	133	7.3
B. R. McPhail	40/2-8D		3/1/60	—	—	0.06	37	13.0	—	—	188	0	—	4.0	—	—	—	190	146	346	7.5
Jule Crabtree	40/2-25A1	20	3/1/60	—	—	0.23[d]	13.0	3.2	3.7	—	44	0	—	4.0	—	—	–	82	46	120	6.6
Delta Water Assoc.	40/3/9R1	37	3/1/60	—	—	0.01	14.0	3.1	—	—	30	0	10.0	6.0	0.1	9.8	—	83	48	131	6.8
K. VanderGriend	40/3-28M	375	3/1/60	—	—	—	180.0	250.0	—	—	120	0	—	4,500.0	—	—	—	—	1,500	14,000	7.5
City of Everson	40/3-36H1	30	4/8/49	48	19	0.01	28.0	12.0	21.0	2.2	44	0	12.0	84.0	0.2	5.6	—	215	119	338	6.6
Andrew Hento	40/4-9A	15	3/2/60	—	—	4.20	7.0	18.0	—	—	20	0	1.4	3.0	—	0.8	—	—	90	195	7.1
John Brayard	40/4-10D1	84	4/8/49	—	48	12.00	14.0	17.0	13.0	2.8	138	0	1.6	14.0	0.2	0.2	—	175	105	245	6.8
James Rorabaugh	40/4-33D		3/1/60	—	—	0.54[d]	14.0	19.0	—	—	130	0	—	—	—	—	—	152	114	290	6.7
H. Kelly	40/5-5-9Q	102	3/2/60	—	—	0.06	18.0	5.5	—	—	74	0	—	—	—	—	—	92	68	152	7.2
City of Blaine	41/1-31Q1	-247	3/26/58	50	26	0.13[d]	14.0	6.8	9.9	4.0	96	0	8.8	2.0	0.1	0.0	0.45	121	63	171	8.0
City of Sumas	41/4-33H	58	3/1/60	—	—	0.00	23.0	4.6	—	—	82	0	—	—	—	—	—	111	76	173	8.1

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

The principal factors that will determine future water demand in the Nooksack-Sumas Basins are population growth and industrial expansion, including agricultural production. As these increase, the demand for water will likewise increase.

PROJECTED POPULATION GROWTH

The estimated 1967 population of 77,300 in the Nooksack-Sumas Basins is projected to increase 19 percent to 91,600 by 1980, 59 percent to 123,500 by 2000, and 117 percent to 168,700 by 2020. Figure 3-4 shows the present and projected population in the Basins. The industrial park development expected for the Bellingham-Ferndale area will cause the majority of the population to center in this immediate urban area, with more than 60 percent of the total Basin population located in the Bellingham area.

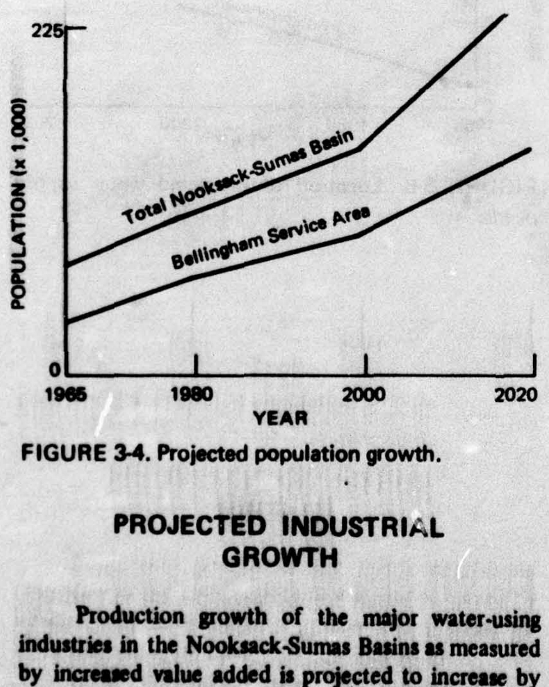


FIGURE 3-4. Projected population growth.

PROJECTED INDUSTRIAL GROWTH

Production growth of the major water-using industries in the Nooksack-Sumas Basins as measured by increased value added is projected to increase by more than three-fold between now and 2020.

It is anticipated that the primary metal, chemical, and petroleum industries will be the major industries in the Basins by 2020. As shown on Figure 3-5, these industries will, by then, account for

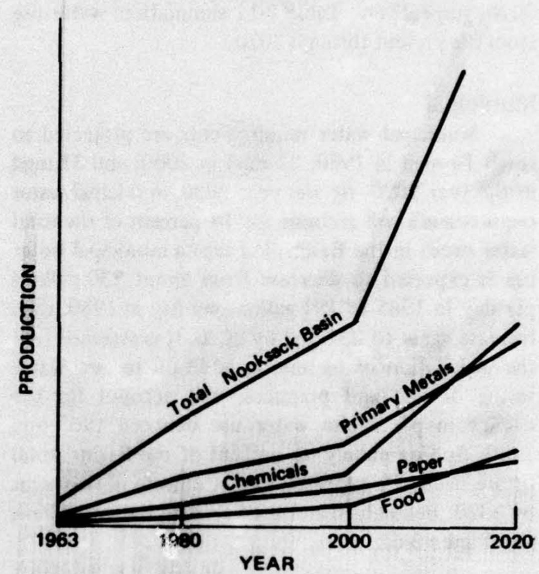


FIGURE 3-5. Relative production growth for major water-using industries.

two-thirds of the total value added by the major water-using industries. This prediction is supported by the recent upsurge in primary metals in the Basins, due notably to the new Intalco aluminum plant at Ferndale, which began operations in 1966.

The Industrial Park west of Ferndale is expected to become the location of an increasing number of industries in the future, including some heavy water users. This growth should generate an urban concentration around the park, extending eastward to Ferndale.

The paper and forest products and agricultural industries are also projected to increase, but at a lower rate. These industries will account for about 22 percent of the total value added by major water-using industries in the Basins by 2020.

PROJECTED WATER REQUIREMENTS

Total water requirements in the Basins by the year 2020 are expected to reach 293 million gallons per day (Table 3-11), more than a three-fold increase over present requirements. Figure 3-6 shows the location of primary municipal and industrial water demand. Surface water sources will supply 97 percent of the projected water needs. Tables 3-8, 3-9, and

3-10 itemize projected water uses in 1980, 2000, and 2020, respectively. Table 3-11 summarizes water use from the present through 2020.

Municipal

Municipal water requirements are projected to reach 14 mgd in 1980, 22 mgd in 2000, and 31 mgd in the year 2020. By the year 2020, municipal water requirements will account for 14 percent of the total water needs in the Basins. Per capita municipal water use is expected to decrease from about 230 gallons per day in 1965 to 191 gallons per day in 1980, then increase again to 231 gpd by 2020. It is assumed that the installation of meters, in addition to new water saving devices and practices, will account for the decline in per capita water use between 1965 and 1980. Approximately 95 percent of the Basins' total future needs are expected to concentrate in two areas by 2020: Bellingham and the Ferndale Industrial Park (see Figure 3-6).

Industrial

Industrial water needs, presently 60 mgd in the Basins, are expected to increase by 235 percent by 1980, and more than double this increase by 2020. Projections of industrial water requirements to 2020 indicate that industries will continue to require the greatest amount of water–about 257 million gallons daily, or 86 percent of the total water needs in the Basins. By 2020, the pulp and paper and aluminum industries are expected to be the major water users in the Basins.

Rural-Individual

By 2020, rural-individual needs are expected to be 2.8 mgd, or less than 2 percent of total projected basin water needs.

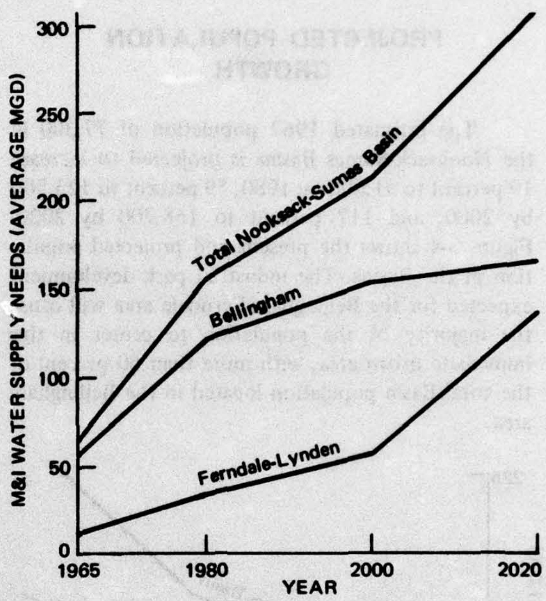


FIGURE 3-6. Location of projected water supply needs.

TABLE 3-8. Projected water use (1980)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Bellingham	55,000	10.50	14.60	—	—
Lynden	4,000	0.80	1.10	—	—
Ferndale	3,000	0.60	0.80	—	—
Blaine, Sumas, Everson and rural community systems	11,300	—	—	2.10	3.00
Subtotal	73,300[e]	11.90	16.50	2.10	3.00
RURAL-INDIVIDUAL USE	18,300	—	—	1.30[a]	1.80
INDUSTRIAL USE					
Municipally supplied:					
Bellingham					
Food and kindred	—	1.45	2.20[b]	—	—
Paper and allied	—	106.50	115.00[c]	—	—
Ferndale					
Food and kindred	—	0.50	0.70[b]	—	—
Lynden					
Food and kindred	—	0.30	0.45[b]	—	—
Self-supplied:					
Food and kindred	—	1.15	1.70[b]	0.35	0.50[b]
Primary metals	—	28.00	28.00	—	—
Petroleum	—	2.80	2.80	—	—
Subtotal	—	140.70	150.90	0.40	0.50
Total[d]	91,600	152.60	167.40	3.80	5.30

[a] Based on assumed 70 gpcd and 100 percent of rural-individual population to be served by ground water.

[b] 150 percent of average.

[c] 110 percent of average.

[d] Figures are rounded.

[e] Not the incorporated areas official municipal population figure. See Table 2-7.

TABLE 3-9. Projected water use (2000)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Bellingham	75,000	15.8	22.0	—	—
Lynden	6,000	1.3	1.8	—	—
Ferndale	8,000	1.7	2.4	—	—
Blaine, Sumas, Everson and rural community systems	13,500	—	—	2.8	4.0
Subtotal	102,500	18.8	26.2	2.8	4.0
RURAL-INDIVIDUAL USE	21,000	—	—	1.9[a]	2.7
INDUSTRIAL USE					
Municipally supplied:					
Bellingham					
Food and kindred	—	2.9	4.3[b]	—	—
Paper and allied	—	130.5	143.5[c]	—	—
Ferndale					
Food and kindred	—	0.9	1.4[b]	—	—
Lynden					
Food and kindred	—	0.6	0.9[b]	—	—
Self-supplied:					
Food and kindred	—	2.3	3.4[b]	0.7	1.0[b]
Primary metals	—	46.0	46.0	—	—
Petroleum	—	4.2	4.2	—	—
Subtotal	—	187.4	203.7	0.7	1.0
Total	123,500	206.2	229.7	5.4	7.7

[a] Based on 90 gpcd and 100 percent of rural-individual population estimated to be served by ground water.

[b] 150 percent of average.

[c] 110 percent of average.

TABLE 3-10. Projected water use (2020)

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Bellingham service area	100,400	23.1	32.2	—	—
Lynden service area	12,000	2.8	3.9	—	—
Ferndale service area	16,000	3.7	5.2	—	—
Blaine, Sumas, Everson and rural community systems	15,000	—	—	3.5	4.9
Subtotal	143,400	29.6	41.3	3.5	4.9
RURAL-INDIVIDUAL USE	25,300	—	—	2.8[a]	3.9
INDUSTRIAL USE					
Municipally supplied:					
Bellingham					
Food and kindred	—	5.3	7.9[b]	—	—
Paper and allied	—	126.5	139.0[c]	—	—
Ferndale					
Food and kindred	—	1.8	2.7[b]	—	—
Lynden					
Food and kindred	—	1.2	1.8[b]	—	—
Self-supplied:					
Food and kindred	—	4.2	6.3[b]	1.3	1.9[b]
Primary metals	—	110.0	110.0	—	—
Petroleum	—	6.7	6.7	—	—
Subtotal	—	255.7	274.4	1.3	1.9
Total[d]	168,700	285.3	315.7	7.6	10.7

[a]Based on 110 gpcd and 100 percent of rural-individual population estimated to be served by ground water.

[b]150 percent of average.

[c]110 percent of average.

TABLE 3-11. Summary of projected water needs

System		Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)		Total usage (mgd)	
			Average daily	Maximum monthly	Average daily	Maximum monthly	Average daily	Maximum monthly
Municipal	1965	59,400	9.3	13.3	1.9	2.6	11.2	15.9
	1980	73,300	11.9	16.5	2.1	3.0	14.0	19.5
	2000	102,500	18.8	26.2	2.8	4.0	21.6	30.2
	2020	143,400	29.6	41.3	3.5	4.9	33.1	46.2
Industrial	1965	—	59.9	64.8	0.6	1.2	60.5	66.0
	1980	—	140.7	150.9	0.4	0.5	141.1	151.4
	2000	—	187.4	203.7	0.7	1.0	188.1	204.7
	2020	—	255.7	274.4	1.3	1.9	256.0	276.3
Rural—Individual	1965	18,300	0.1	0.2	0.9	1.3	1.0	1.5
	1980	18,300	—	—	1.3	1.8	1.3	1.8
	2000	21,000	—	—	1.9	2.7	1.9	2.7
	2020	25,300	—	—	2.8	3.9	2.8	3.9
Totals	1965	77,700	69.3	78.3	3.4	5.1	72.7	83.4
	1980	91,600	152.6	167.4	3.8	5.3	156.4	172.7
	2000	123,500	206.2	229.9	5.4	7.7	211.6	237.6
	2020	168,700	285.3	315.7	7.6	10.7	292.9	326.4

Note: All usage figures are rounded to one decimal place. *All basins are summarized in Table 2-9.*

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 293 mgd by the year 2020. This is an increase of approximately 220 mgd over the 1965 average use. Optimum or peak water requirements will be nearly 370 mgd. Tables 2-12 and 2-13, the Area Plans, summarize the Basins' annual average and optimum requirement in relation to the remainder of the Area. Table 3-12, Municipal and Industrial Water Supply Needs, reviews the needs of the major systems and/or users in the Basins.

The Bellingham Municipal Water System, drawing from surface sources, is expected to supply more than 70 percent of the total municipal water requirements (as treated water) and, in addition, to supply more than 50 percent of the total industrial water requirements (as diverted from Lake Whatcom with chlorination) in the entire Nooksack-Sumas Basins. Bellingham must, therefore, be able to supply more than 210 mgd, approximately 60 percent of the total basin water requirement, to municipal and industrial users.

The water systems of Lynden and Ferndale are expected to supply 9.7 mgd, 3 percent, and 13.5 mgd, 4 percent, of the total basin requirement, respectively. The remaining water will be supplied by the Whatcom County PUD, Industrial Water Development, and small community systems. This will amount to 128.4 mgd or 34% of the Basin total. The municipal and industrial water needs projected for 2020 can be met by water available in the Basins without need for storage. Although a plentiful source of surface water is available, the projected population and industrial growth will require larger systems to satisfy requirements.

BASIN PLAN

The Selected Plan recommends the continuing use of existing sources until such time as the

TABLE 3-12. Municipal and industrial water supply—capital improvements, Nooksack-Sumas Basins

	M.G.D. Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	36,500	55,000	75,000	100,400
BELLINGHAM				
Optimum	79.1	153.4	197.1	212.9
Capital improvements	18.1	74.3	43.7	15.8
Population Served	1,850	3,000	8,000	16,000
FERNDALE				
Optimum	2.0	2.7	6.7	13.3
Capital improvements	0.8	0.7	4.0	6.6
Population Served	2,850	4,000	6,000	12,000
LYNDEN				
Optimum	2.0	2.9	4.9	9.7
Capital improvements	1.3	0.9	2.0	4.8
Population Served	9,200	11,300	13,500	15,600
SMALL AND RURAL COMMUNITY SYSTEMS				
Optimum	6.0	7.5	8.9	9.9
Capital improvements	3.6	1.5	1.4	1.0
Population Served	–	–	–	–
SELF-SUPPLIED INDUSTRY				
Optimum	12.2	33.0	53.6	124.9
Capital improvements	0.4	20.8	20.6	71.3
Population Served	53,400	73,300	102,500	144,000
TOTAL CAPITAL IMPROVEMENTS	24	98	72	100

Note: Figures are rounded.

population density can provide adequate revenue to finance county or regional water systems.

Table 3-13 defines the plan and includes supply and transmission, treatment, pumping, chemical, and annual income as projected by the Municipal and Industrial Water Supply and Water Quality Control Technical Committee. Table 2-12 includes the storage and distribution costs for the Basins. Table 2-10 depicts supply and transmission costs on a population density basis.

The Alternative Basin Plan, Table 3-14, was based upon the use of both surface and ground water sources, depending upon which source would be more capable of meeting the future needs adequately by a second surface source for replacing the existing Middle Fork division.

Costs for the Alternative Plan are only $1.5 million greater than the Selected Basin Plan. This is evidenced by the fact that the two basin plans are not greatly different for the city of Bellingham.

Bellingham presently supplies 57 mgd to its municipal and industrial consumers. This need is expected to reach 155 mgd by 2020. The present Bellingham system, from the Middle Fork of the Nooksack River, is diverted to Lake Whatcom, which is used as a settling basin, then delivered to the customers. Treatment is supplied for municipal use only.

The Selected Plan calls for the city to develop a second municipal source on the Main Fork of the Nooksack River and provide additional treatment. The industrial demand would be met by a river intake on the main stem of the Nooksack River above tidal intrusion.

The remainder of the Basins is expected to develop by 2020 approximately 160 mgd from expansion of existing systems. Most of the water, 125 mgd, will be used by the self-supplied industries in the Basins. Table 3-12, Present and Future Needs,

TABLE 3-13. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Nooksack-Sumas Basins

					OPTIMUM CAPACITY M G D[d]		1967 THOUSAND DOLLARS: AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
BELLINGHAM												
Present	SW	Diversion to Lake Whatcom from Middle Fork Nooksack River and Treatment (Municipal)	Exist	57	61	61				640		7,008
	SW	ADD: 18mgd to Existing	1965		18	18	1,940	1,380			24	
1980	SW	Middle Fork Nooksack River Diversion and Settling Pond before L. Whatcom	1970	119	10	10	2,260	1,380		1,248	48	9,773
		[a]Diversion and Treatment Main Nooksack Rivers near Bellingham			65	65	4,360					
2000	SW	Middle Fork Nooksack River Diversion Increased	1990	149	15	15	1,850	983		1,565	60	12,237
		Increase Main River Diversion			30	30	3,870					
2020	SW	Increase Middle Fork Nooksack River Diversion Capacity	2010	155	15	15	2,080	1,478		1,628	62	11,315
BELLINGHAM SELECTED PLAN TOTAL					214	214	$16,360	$5,221				
							$21,581					
FERNDALE												
Present	GW	Local Ground Water Development	Exist	1	1.2	1.2				6		117
1980	GW	ADD: Development for 0.8mgd	1970		0.8	0.8	48					
1980	GW	Local Ground Water Development Development for 0.7 mgd	1975	1	0.7	0.7	42			11		117
2000	GW	Local Ground Water Development Development for 4.0mgd	1990	3	4.0	4.0	240			27		117
2020	GW	Local Ground Water Development Development for 6.6mgd	2005	6	6.6	6.6	396			58		234
FERNDALE SELECTED PLAN TOTAL					13.3	13.3	$726					
LYNDEN												
Present	SW	Water Treatment Plant, Nooksack River	Exist	0.6	0.7	0.7				6	0.2	117
		ADD: SW Treatment Capacity 1.5mgd			1.5	1.5	196	112				
					2.2	2.2						
1980	SW	SW Treatment Capacity 0.9mgd	1975	1.1	0.9	0.9	117	88		10	0.4	117
2000	SW	SW Treatment Capacity 2.0mgd	1985	2.3	2.0	2.0	260	150		19	0.7	117
2020	SW	SW Treatment Capacity 4.8mgd	2015	4.9	4.8	4.8	624	360		42	1.6	234
LYNDEN SELECTED PLAN TOTAL					10	10	$1,196	$690				
							$1,886					
SELF SUPPLIED INDUSTRY												
1965	SW–GW	Local Development: Untreated, clarified	Exist	12	12	12				128		1,402
1980	SW–GW	Local Development: Net 21.8mgd	1970	32	22	22	2,730			336		3,737
2000	SW–GW	Local Development: Net 126mgd	1990	53	114	114	1,640			567		15,534
2020		No Future Need		123						1,331		14,366
SELF–SUPPLIED INDUSTRY SELECTED PLAN TOTAL					148	148	$4,370					
SUMAS–BLAINE & OTHER RURAL COMMUNITIES												
Present	GW	Local GW Development	Exist	2	2.4	2.4				15		
1980	GW	Local GW Development	1970		3.6	3.6	216					117
					6.0	6.0						
1980	GW	1.5mgd Local Ground Water Development	1980	2	1.5	1.5	90			22		117
2000	GW	1.5mgd Local Ground Water Development	1995	3	1.4	1.4	84			29		117
2020	GW	1.0mgd Local Ground Water Development	2010	4	1.0	1.0	60			37		117
SUMAS–BLAINE & OTHER RURAL COMMUNITIES SELECTED PLAN TOTAL					10	10	$450					
SELECTED BASIN PLAN TOTAL							$30,963[c]					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.5 gpm per service connection plus the maximum industrial monthly demands.

TABLE 3-14. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Nooksack-Sumas Basins

					OPTIMUM CAPACITY M G D[d]		1967 THOUSAND DOLLARS AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
BELLINGHAM												
Present	SW	Diversion to Lake Whatcom from Middle Fork Nooksack River Existing Water Treatment Plant	Exist.	60	61	61				640		7,008
1980	SW	Supply and Transmission: 18mgd and Water and Treatment 18mgd	1975		18	18	2,340	1,980			24.4	
1980	SW	[a]Storage Dam, Reservoir–North Fork Nooksack River	1980		74	74	9,620			1,248	47.5	9,773
2000	SW	Storage Dam, Reservoir–North Fork Nooksack River ADD: To Treatment 30mgd	1995	149	44	44	5,720	983		1,565	59.5	12,237
2020	SW	Storage Dam, Reservoir–North Fork Nooksack River	2010	155	16	16	2,080	1,478		1,628	62.0	11,315
					213	213	$19,760	$4,441				
BELLINGHAM ALTERNATIVE PLAN TOTAL							$24,201					
FERNDALE												
Present	GW	Local Ground Water Development ADD: 0.8mgd	Exist.	1	1.2 0.8 2.0	1.2 0.8 2.0	48			6		117
1980	SW	[a]Intake and Treatment Plant 2.7mgd, Nooksack River	1970	1	3.0	3.0	390	200		11	0.4	117
2000	SW	Treatment and Capacity 4.0mgd	1990	3	4.0	4.0	520	300		27	1.1	117
2020	SW	Treatment and Capacity 7.0mgd	2010	6	7.0	7.0	520	300		38	2.2	234
					16.0	16.0	$1,478	$800				
FERNDALE ALTERNATIVE PLAN TOTAL							$2,278					
LYNDEN												
Present	SW	Water Treatment Plant and Intake (Nooksack R)	Exist	1	0.7	0.7				6	0.2	117
1980	GW	[a]Local Ground Water Development and 3.0mgd	1970	1	3	3	180			11		117
2000	GW	Local Ground Water Development and 5.0 mgd	2000	2	5	5	300			19		117
2020	GW	Local Ground Water Development and 2.0mgd	2020	4	2	2	120			42		234
LYNDEN ALTERNATIVE PLAN TOTAL					11	11	$ 600					
RURAL COMMUNITIES (No Feasible Alternates)							$450					
SELF SUPPLIES INDUSTRY (No Feasible Alternates)							$4,370					
ALTERNATIVE BASIN PLAN TOTAL							$ 31,899					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.6 gpm per service connection plus the maximum industrial monthly demands.

shows the water required by the major consumers in the Basins to 2020.

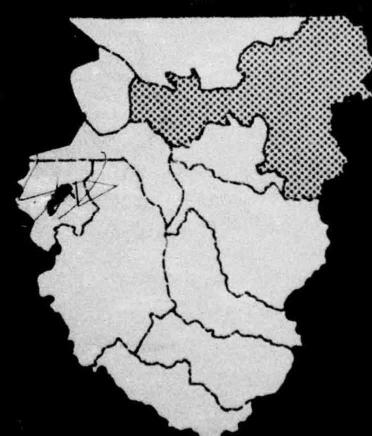
FINANCE

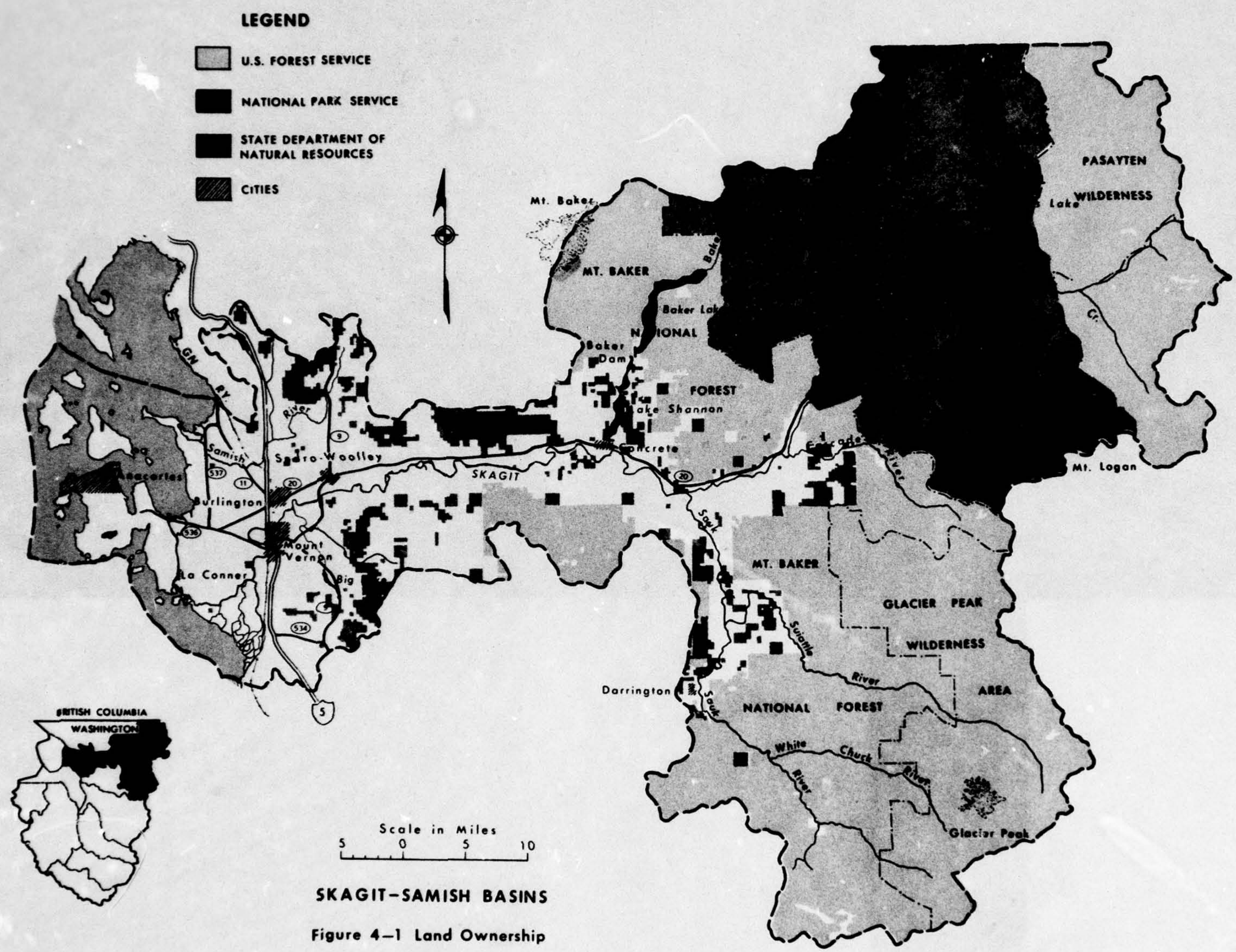
Annual income, as taken from Table 2-12 (the income remains the same for the Selected and Alternative Plans), indicates the monies available to apply for bond service (approximately 20 percent of the total annual income). The following figures show the amount of money available for bond service and the capital expenditure amortized for 30 years at 5% for the Selected and Alternative Plans:

Year	Bond Service Available (X $1,000)	Annual Amortized Cost (X $1,000) Selected Plan	Alternative Plan
1965	$1,850	$365	$272
1980	2,960	591	609
2000	6,030	658	674
2020	5,630	665	650

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. As the above figures depict, the Nooksack-Sumas Basins will have adequate money to construct the water facilities needed through 2020.

Skagit-Samish Basins





SKAGIT–SAMISH BASINS

Figure 4–1 Land Ownership

SKAGIT-SAMISH BASINS

INTRODUCTION

The Skagit-Samish Basins occupy some 3,184 square miles on the western slope of the Cascade Range in the northern part of the Puget Sound Area. The Basins lie between the Nooksack-Sumas Basins and British Columbia on the north and the Stillaguamish and Snohomish Basins on the south and extends easterly from Skagit Bay, Anacortes, and Cypress Island to the summit of the Cascade Range (see Figure 4-1).

Because of the abundance of natural resources in the Skagit-Samish Basins, and its proximity to the densely population Seattle-Everett area, industrial and population growth is predicted to increase the water demands for the year 2020 by a factor of four over present requirements. Although this demand will not tax the water supply available from the Skagit River alone, it will require rational planning for future development of water handling and treating facilities. This is particularly true in the Anacortes vicinity. The major portion of industrial and population growth is expected to occur there.

GEOGRAPHY

The Skagit-Samish Basins offer extremes in geography and topography. The eastern portion of the Basins above Marblemount is rugged, mountainous, nearly wilderness territory that includes Mount Logan and, on the northern perimeter, Mount Baker which, with an elevation of 10,000 feet, is one of the major peaks in the Puget Sound Area. More than 270 glaciers are located in this portion of the Basin. Between Marblemount and Sedro Woolley, the terrain remains somewhat mountainous, but is cut by broad, deep valleys through which the major rivers flow. Below Sedro Woolley, the terrain changes to a broad lowland flood plain, beyond which lies the vast Skagit delta.

The Skagit River and its major tributaries, the Baker, Cascade, and Sauk Rivers, head in glaciated peaks on the northern and eastern perimeters of the Basin. The Skagit drains the northwestern, central, and western portions of the Basin; the Cascade drains the east-central portion; the Sauk and its tributary river, the Suiattle, drain the southeastern portion of the Basin; and the Baker River drains the north-central sector before joining the Skagit below Concrete. This river system drains an area of 3,105 square miles, about 400 square miles of which is in Canada (see Figure 4-1). (The drainage area in Canada is not included in this study). The Skagit (Photo 4-1) flows from its headwaters in Canada, then divides into two branches about 8 miles before it empties into Puget Sound at Skagit Bay.

Located in the rough upland terrain south of Bellingham, the Samish River drainage area comprises 106 square miles. The Samish River and its main tributary, Samish Creek, outlet of Samish Lake, form the most important drainage system in this area. The Samish River flows in a southwesterly direction from its junction with Samish Creek across a broad glacial plain from where it flows northwest to its outlet at Samish Bay near Edison.

PHOTO 4-1. The Skagit River, largest in the Puget Sound Area, provides recreation, power generation, and a vast water supply potential.

CLIMATE

Maritime air masses influence both precipitation and temperature in the Skagit-Samish Basins to produce a mild, wet climate. Recorded mean annual precipitation varies from about 109 inches at Mount Baker Lodge to 27 inches at Anacortes. Sedro Woolley, nearly 20 miles farther inland than Anacortes, receives 46 inches; and Concrete, in the mountain foothills, receives 62 inches. During the winter, heavy snowfall occurs at higher elevations and remains until late spring or early summer. Average recorded snowfall ranges from 530 inches at Mount Baker Lodge to 5.9 inches at Anacortes. About 75 percent of the annual precipitation falls during October through March.

Mean annual temperatures vary from 4.4°C (40°F) at Mount Baker Lodge to 11.1°C (52°F) at Concrete, and recorded temperature extremes range from -11.7°C (11°F) to 41.1°C (106°F) at these stations, respectively. The mean annual temperature for the Basin is 10°C (50°F).

POPULATION

A 1967 estimate revealed that about 56,900 persons live in the Skagit-Samish Basins. About 8,750 live in Anacortes, largest city in the Basins, and about 17,108 live in smaller towns such as Mount Vernon, Burlington, and Sedro Woolley. Most of the remainder live in or about small rural communities scattered throughout the central and western portions of the Basins.

ECONOMY

The economic base is diversified, made up of agriculture, forest products, fisheries, food processing, manufacturing, and oil refining industries. The tideflats and bottom lands support an agricultural economy largely based on dairy products, vegetables, feed crops, and berries. Frozen food processing is big business. Most of the green peas, sweet corn, cauliflower, broccoli, and carrots are shipped to local processors in Mount Vernon, Burlington, and LaConner.

LAND USE

The Skagit-Samish Basins is lightly urbanized, with urban developments accounting for less than 1 percent of the total land area. Forest land accounts for nearly 70 percent of the total land area, and cropland (Photos 4-2 and 4-3) and rangeland combined account for about 6 percent of the land area. Table 4-1 lists present land use in the Basins.

PHOTO 4-2. Farmlands near Sedro Woolley present a patchwork pattern.

PHOTO 4-3. Cropland, much of it irrigated, covers about 5 percent of the land in the Basin.

TABLE 4-1. General land use

Use	Acres
Forestland	1,754,000
Cropland	100,000
Rangeland	20,000
Other land (high, barren)	20,000
Urban buildup	19,000
Inland water	35,000
Salt water	101,395
Total land and inland water*	1,948,000

*Source: Appendix III, Hydrology.

PRESENT STATUS

The Skagit-Samish basin is only lightly populated and the population is well distributed about the western portion of the basin. Because of this, and because of the availability of plentiful supplies of water, demands for water in the basin are presently well within the capabilities of sources developed to supply them.

WATER USE

Municipal, industrial, and rural water use in the Skagit-Samish basin presently averages 27.9 mgd (43.5 cfs). Of this amount, the municipal and rural component accounts for 5.1 mgd, or 18 percent of the total water use. Industrial water requirements, which make up the remainder, are more than twice as great as the municipal and rural use. Table 4-2 shows a breakdown of basin water use as of 1965.

TABLE 4-2. Water use (1965)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Surface water usage (mgd) Maximum daily	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Ground water usage (mgd) Maximum daily
MUNICIPAL USE							
Anacortes	8,750	1.40	1.60	2.50	—	—	—
Skagit County PUD No. 1	23,500	2.00	2.50	3.00	—	—	—
Northern State Hospital	1,680	—	—	—	0.41	0.43	0.45
Darrington	1,400	—	—	—	0.15	0.30	0.45
Concrete	700	—	—	—	0.09	0.16	0.24
Lyman	430	0.02	0.03	0.04	—	—	—
Hamilton	209	—	—	—	0.04	0.04	0.05
Other rural community systems	2,100	0.05	0.10	0.14	0.14	0.21	0.31
Subtotal	40,230[b]	3.47	4.23	5.68	0.83	1.14	1.50
RURAL-INDIVIDUAL USE	15,270	0.09[a]	0.18	0.27	0.75[a]	1.56	2.31
INDUSTRIAL USE							
Municipally supplied:							
Anacortes:							
Pulp and paper		5.50	6.00	6.10	—	—	—
Petroleum and refining		7.00	7.20	7.80	—	—	—
Chemicals		0.13	0.15	0.16	—	—	—
Naval Air Base (Whidbey Island)		1.00	1.40	1.80	—	—	—
Food processing		0.34	0.39	0.45	—	—	—
Skagit County PUD No. 1:							
Food processing		4.60	6.00	6.80	—	—	—
Chemicals, metals, oils		1.70	2.50	3.30	—	—	—
Other		0.55	0.74	0.85	—	—	—
Self-supplied:							
Food and kindred		1.68	2.20	2.80	—	—	—
Stone, clay, glass		0.27	0.30	0.40	—	—	—
Subtotal		22.77	26.88	30.46	—	—	—
Total	55,500	26.33	31.29	36.41	1.58	2.70	3.81

[a] Based on assumed 55 gpcd.

[b] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

Municipal

A total of 40,230 municipal consumers in the Basins use an average of 4.3 mgd, 15 percent of the total basin water requirements, for a basin-wide per capita use of 107 gpd. About 10,000 municipal consumers in the Anacortes area use an average of 1.4 mgd for a daily per capita use of 140 gpd and about 17,108 persons in the numerous small communities in the central portion of the Basins use 2.0 mgd for a daily per capita use of 89 gpd. An additional 6,730 municipal consumers, comprising those in Northern State Hospital and numerous small, scattered communities, use about 0.9 mgd for a per capita use of 134 mgd.

Industrial

Industrial firms in the Basins use water at an average rate of 22.77 mgd. The chief industrial users are Scott Paper Company and the Shell and Texaco petroleum refineries, served by the Anacortes system, which use a total of 14 mgd. The Scott Paper Company uses 5.5 mgd in processing 138 tons of pulp per day for an average of 40,000 gallons of water per ton of pulp. The Shell and Texaco refineries, with a combined production of 118,000 barrels of gasoline and fuel oils per day, use a total of 7.0 mgd, a unit use of 58 gallons of water per barrel of refined fuel.

The remaining industries in the Basins, including Whidbey Island Naval Air Station and chemical, metal, and food processing industries, show a combined usage of 8.8 mgd.

Rural-Individual

About 15,270 rural-individual consumers use 0.84 mgd, based on an estimated average per capita consumption of 55 gpd.

WATER SUPPLIES

Surface water provides 94 percent (26.3 mgd) of the average daily municipal, industrial, and rural-individual water requirements in the Basins. Ground water furnishes the remaining 6 percent (1.6 mgd).

Municipal

The two major systems, Anacortes and the Skagit County PUD No. 1, rely primarily on surface water for their source of supply. Most of the remaining systems, which are small public or rural-individual, use ground water.

Anacortes—The Anacortes municipal system serves an estimated 10,000 municipal consumers and numerous industries, including chemical, metal, oil, and pulp and paper industries, with an average of 13.0 mgd. In addition, the Anacortes system provides an average of 1.0 mgd to the Whidbey Island Naval Air Base. Although the total average amount of water supplied by this system is 15.0 mgd, maximum demands can exceed 21.0 mgd.

Anacortes obtains its water supply from two Ranney wells located in the vicinity of Avon on the east bank of the Skagit River north of Mount Vernon. The Ranney wells are supplied primarily by infiltration (estimated 90 percent) from the Skagit River. This supply is supplemented during drier summer months by pumping directly from the Skagit River into the Ranney wells. The water, after treatment, is pumped through a transmission line across the Swinomish flats for about 12 miles to Anacortes. The combined capacity of the Ranney wells during low river stages is 14.8 mgd (20.8 mgd at average river stages), and the Skagit River pumping plant can supply 6 mgd. During peak use periods, the present system, including storage, is barely able to meet demands.

Skagit County PUD No. 1—Skagit County PUD No. 1 provides about 23,500 persons and several industries with an average of about 8.9 mgd. However, the major industrial consumers, several food processing plants, create a demand for water during July and August that more than doubles system average requirements.

Water for PUD No. 1 is obtained principally from five small streams in the Cultus Mountain watershed. This watershed, lying on the western extremity of the Cascade Mountains about 9 miles east of Mount Vernon, is under private and State ownership, and is not managed by the district. Water is diverted from the streams and conveyed through 26 miles of pipeline to Judy Reservoir, which has a storage capacity of 3,050 acre-feet. Present capacity of the supply lines to the reservoir is estimated to be 8 mgd. The watershed contributing to the reservoir has a drainage area of 13.7 square miles and an average annual runoff of 40,000 acre-feet.

Transmission line capacity from the reservoir to the PUD distribution system is 12.5 mgd. A Ranney well with a capacity of 4 mgd located in north Mount Vernon and a conventional well in Sedro Woolley with a capacity of 1 mgd, provides secondary sources

of supply. In addition, 2-mgd pumping and water treatment plant located in Mount Vernon utilizes the Skagit River to satisfy peak demand and as a standby service if other sources fail. Peak day capacity of all sources is 19.5 mgd. Three small wells (combined capacity 80 gpm) serve the area on Fidalgo Island.

The quality of the PUD's water supply is acceptable for drinking water, although the color of the Cultus Mountain water sometimes exceeds desirable levels. The only treatment the supply receives is disinfection.

Industrial

Virtually all industries obtain their water supply from either the Anacortes municipal system or Skagit County PUD No. 1, though two sand and gravel operations and two ready-mix concrete plants supply their own water needs, diverting an average of 0.28 mgd from surface sources.

The Anacortes municipal system supplies an average of 14.0 mgd and Skagit County PUD No. 1 supplies an average of 6.85 mgd to various industrial users in the Basins.

Rural-Individual

An estimated 15,270 persons obtain water from about 4,610 individual systems, of which about 90 percent are supplied by ground water.

WATER RIGHTS

The city of Anacortes has water rights for 135.0 cfs (87 mgd) on the Skagit River, 4 cfs (2.6 mgd) from Lake Erie, and 1,000 acre-feet per year (0.9 mgd) from Lake Campbell. Skagit County PUD No. 1 has two water right applications on Day Creek to divert a total of 62 cfs (40 mgd), an application on the East Fork of Nookachamps Creek for 15.2 cfs (9.7 mgd), and nine applications on various creeks in the Cultus Mountain watershed for a total of 53.4 cfs (34.4 mgd).

Surface and ground water rights applications, permits, and certificates for municipal, industrial, and domestic water supply and irrigation purposes in the Skagit Basin are summarized as of December 1, 1965, in Table 4-3.

TABLE 4-3. Municipal and industrial water rights

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	104.3	36.6	19.1
Ground water	24.4	12.0	5.4
Total [a]	128.7	48.6	24.5

[a]About 24,322 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

Adequate water resources exist in the Skagit Samish Basins for all predictable requirements to the year 2020. Surface water alone will provide many times the demand, even under the worst expected drought conditions.

SURFACE WATER

Surface water resources are more than adequate to provide a plentiful supply of water to the Basins, even under the most adverse conditions. In addition, because of the isolation of the Basin watersheds, contamination is unlikely to occur.

Quantity Available

Streams—The Skagit Basin produces more runoff than any other basin. The average annual discharge of the Skagit River into Skagit Bay was about 11.8 million acre-feet during the period from 1931 through 1960.

The average discharge of the Skagit River ranges from 4,418 cfs (1931-1960) at Newhalem to 16,250 cfs (1931-1960) at Mount Vernon. The maximum recorded discharge at Mount Vernon was 144,000 cfs (February 11, 1951) and the minimum was 2,740 cfs (October 26, 1942). The average annual runoff of the Samish River is about 193,000 acre-feet.

Numerous glaciers in the Basin regulate streamflows by practically eliminating extreme lowflows during dry summer months. At higher altitudes, the minimum runoff occurs in February or March, but at lower elevations the minimum flow in tributary

streams normally occurs in September. Streamflow usually begins to increase in September or October from the summer base flow of approximately 9,000 cfs. From October to March the streamflow is characterized by a series of sharp rises superimposed on an increasing base flow, which is highest in December. As temperatures begin to rise in April, snowmelt causes an increase in streamflow, which usually reaches an average discharge of 25,000 cfs at Concrete by the middle of June.

A lowflow frequency analysis has been made for 25 stations within the Skagit-Samish Basins by the U.S. Geological Survey. The 7-day and 30-day low-flows for recurrence intervals of 5, 10, and 20 years for five selected stations in the Basins are shown in Table 4-4.

TABLE 4-4. Low-flow frequency.

Discharge station	Recurrence interval (years)	7-day low-flow (cfs)	30-day low-flow (cfs)
Skagit River at Newhalem	5	1,400.0	2,000
	10	1,200.0	1,600
	20	1,100.0	1,300
Skagit River near Concrete	5	5,300.0	6,300
	10	4,700.0	5,500
	20	4,200.0	4,900
Sauk River near Sauk	5	1,010.0	1,220
	10	860.0	1,050
	20	730.0	900
Skagit River near Mount Vernon	5	5,800.0	6,700
	10	5,100.0	5,800
	20	4,600.0	5,200
Samish River near Burlington	5	21.5	24
	10	19.5	21
	20	17.8	19

Lakes, Dams and Impoundments—Impoundments in the Basins cover 40.5 square miles only; 9.1 square miles of which are natural, the remaining area represents reservoirs used for power generation. The largest of the impoundments, Ross Lake on the Upper Skagit River, has a total storage of 1,434,000 acre-feet. Two other impoundments on the Skagit River, Diablo Reservoir and Gorge Reservoir have total capacity of 89,000 and 8,500 acre-feet, respectively. Baker Lake (298,000 acre-feet) and Lake Shannon (159,000 acre-feet) are both located on the Baker River.

Quality

Water quality data have been obtained by the U.S. Geological Survey and the Washington Water Pollution Control Commission for the Skagit River at Marblemount and Mount Vernon, for the Baker River at Concrete, for the Sauk River near Darrington, and for the Samish River near Burlington. The period of record for these stations is shown in Table 4-5.

Physical—Stream temperatures of rivers in the Skagit-Samish Basins are moderately low. The highest recorded temperature was 19.0°C (66.2°F), taken in the Samish River near Burlington. This river, because of its location and source, has an average temperature somewhat higher than that of other rivers in the Basins. Other maximum recorded temperatures are: 17.8°C (64°F) for the Skagit River at Mount Vernon, 15.2°C (59.4°F) for the Skagit at Marblemount (farther upstream), 13.0°C (55.4°F) for the Sauk River near Darrington, and 16.7°C (62.1°F) for the Baker River at Concrete.

Sedimentary material transported by the various rivers varies greatly in volume between normal flow periods of high runoff. An analysis of data obtained in 1965 and 1966 indicates that the Skagit River can be expected to transport a sediment load of 10 million tons during a year of normal streamflow. When the river discharge is about 70,000 cfs, a daily sediment load of about 640,000 tons can be expected. Observed concentrations of suspended sediments in the Skagit River near Mount Vernon ranged from 19 to 654 mg/l during 1965 to 1966.

The Samish River, heading in low mountains south of Bellingham, may transport a total sediment load of 10,000 tons during a year of normal streamflow. When the flow of the Samish River near Burlington is 5,000 cfs, a daily sediment load of about 4,000 tons can be expected. Observed concentrations of suspended sediment ranged from 6 to 60 ppm during 1965 and 1966.

The Skagit River becomes more turbid between Marblemount and Mount Vernon because of changes in land use. Turbidity in the lower Samish River is comparable to that of the lower Skagit River.

Chemical—The chemical quality of surface waters in the Skagit-Samish Basins is generally excellent. Dissolved solids content range from 18 to 44 mg/l and values of hardness range from 12 to 30 mg/l in the Skagit River at Marblemount. The amount of dissolved mineral in the Skagit River water increases only slightly downstream. Near Mount Vernon, the dissolved solids content ranges from 0 to 52 mg/l and hardness values range from 13 to 32 mg/l. Water in

the Samish River has only a slightly greater mineral content than water in the Skagit River. Maximum dissolved solids content and values of hardness recorded for this river are 71 and 44 mg/l, respectively (see Table 4-5).

The Skagit River and its major tributaries are relatively fast-moving water courses. Dissolved oxygen (DO) concentrations throughout the length of the Skagit River are near saturation. At Mount Vernon, on the lower Skagit River, DO concentrations range from a recorded low of 9.3 mg/l to a high of 13.7 mg/l. The lowest DO concentrations recorded on the Sauk and Baker Rivers were 10.2 and 9.7 mg/l, respectively, indicating slightly higher concentrations in these faster moving tributaries. Dissolved oxygen concentrations in the Samish River north of Burlington and Sedro Woolley range from 7.0 to 13.0 mg/l.

Bacteriological—The bacteriological quality of the Skagit River is satisfactory, but indicates a general trend of decreasing quality downstream from Marblemount. The most probable number of coliform organisms per 100 ml (MPN) ranges from a low of 0 to a high of 230 at Marblemount, but is generally less than 50 per 100 ml. This very low average is typical of a stream draining remote mountain areas. High MPN values occur downstream from Marblemount as a result of domestic and livestock wastes associated with increased population density. At Mount Vernon, coliform densities range from a low of 0 MPN to a maximum 24,000 MPN. The normal MPN values for this station range from about 91 to 4,600. Bacteriological counts from the Sauk and Baker Rivers indicate that water from these rivers is usually higher quality than that from the Skagit River. The maximum recorded MPN values obtained on the Sauk River and Baker River are 2,400 and 930 coliforms per 100 ml, respectively. The MPN values obtained for the Samish River near Burlington indicate a range of 0 to 11,000 coliforms per 100 ml.

GROUND WATER

Ground water in the Basins is a plentiful commodity in most basin areas, and is sufficient to supply users now drawing from that source (mostly rural-individuals). However, quality of the ground water is variable, and in some areas is marginal for domestic or industrial use. Also, shallow ground water in highly urbanized areas is subject to contamination because of the influence of the surface.

Quantity Available

Ground water occurs at shallow depths over most of the Skagit River delta area. Fairly large

TABLE 4-5. Surface water quality.

Item	Discharge (cfs)	Dissolved solids (mg/l)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2) (mg/l)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Hardness: Total	Hardness: Noncarbonate	Coliform (MPN)
		mg/l												mg/l									ny/l				
SKAGIT RIVER AT MARBLEMOUNT — JULY 1959 THROUGH 1966																											
Maximum	11,700	44	10.0	1.4	1.2	0.9	35	0	5.2	0.5	0.2	1.1	70	0.08	--	6.5	0.23	0.04	8.0	5	5	15.2	13.3	131	30	2	230
Mean	--	32	7.5	0.8	0.8	0.5	26	0	3.7	0.1	0.1	0.3	51	0.01	--	5.1	0.07	0.01	--	--	--	8.3	11.7	103	22	1	40
Minimum	4,120	18	4.0	0.1	0.6	0.2	15	0	2.2	0.0	0.0	0.0	30	0.00	--	3.0	0.01	0.00	6.8	0	0	3.6	9.7	89	12	0	0
Number	29	36	36	36	36	36	36	23	36	36	36	36	36	33	--	36	33	11	36	36	15	37	37	37	36	36	37
SAUK RIVER ABOVE WHITECHUCK RIVER NEAR DARRINGTON — JULY 1959 THROUGH 1961																											
Maximum	2,500	52	7.0	1.7	2.8	0.9	29	0	7.0	1.3	0.2	0.9	66	0.08	--	13.0	0.28	0.02	7.9	15	40	13.0	13.7	108	24	2	2,400
Mean	--	32	5.1	1.0	1.3	0.5	20	0	3.7	0.7	0.1	0.2	44	0.02	--	8.0	0.09	0.01	--	--	--	7.4	11.8	101	17	0	153
Minimum	201	18	3.0	0.2	0.7	0.3	13	0	0.9	0.0	0.0	0.0	28	0.00	--	5.2	0.01	0.00	5.7	0	0	2.0	10.2	91	11	0	0
Number	17	17	17	17	17	17	17	4	17	17	17	17	17	17	--	17	17	2	17	16	15	17	17	17	17	17	17
BAKER RIVER AT CONCRETE — NOVEMBER THROUGH AUGUST 1965																											
Maximum	5,770	56	11.0	1.8	2.4	0.8	37	0	9.8	1.0	0.1	0.5	81	0.03	--	8.4	0.81	0.04	7.5	15	40	16.7	13.8	114	35	6	930
Mean	--	37	6.7	1.0	1.6	0.6	21	0	7.2	0.5	0.1	0.3	52	0.01	--	6.8	0.26	0.02	--	--	--	9.4	11.3	101	21	4	72
Minimum	332	24	4.5	0.5	1.1	0.3	15	0	5.0	0.2	0.0	0.1	36	0.00	--	4.7	0.09	0.00	6.9	0	0	4.0	9.6	90	14	1	0
Number	12	16	16	16	16	16	16	16	16	16	16	16	16	16	--	16	15	8	16	--	--	16	16	16	16	16	15
SKAGIT RIVER NEAR MOUNT VERNON — JULY 1959 TO PRESENT																											
Maximum	50,800	52	10.0	2.2	2.0	1.0	38	0	8.6	1.5	0.2	1.5	76	0.07	--	9.0	2.00	0.06	8.1	20	350	17.8	13.7	127	32	7	24,000
Mean	--	35	7.0	1.2	1.2	0.6	26	0	4.2	0.4	0.1	0.4	53	0.02	--	6.4	0.32	0.02	--	--	--	9.3	11.2	100	22	1	1,849
Minimum	6,380	0	4.5	0.3	0.7	0.2	16	0	2.0	0.0	0.0	0.0	36	0.00	--	4.2	0.01	0.00	6.3	0	0	4.0	9.3	80	13	0	0
Number	84	86	86	86	84	84	86	33	86	86	84	86	86	73	--	86	73	11	84	84	44	87	88	87	86	86	87
SAMISH RIVER NEAR BURLINGTON — JULY 1959 TO PRESENT																											
Maximum	784	71	12.0	4.3	4.2	1.4	52	0	7.1	4.0	0.5	4.7	108	0.08	--	12.0	1.80	0.04	7.8	40	90	19.0	13.0	108	44	6	11,000
Mean	--	49	7.4	2.2	2.8	0.7	30	0	4.8	2.2	0.1	2.2	71	0.03	--	7.9	0.40	0.01	--	--	--	9.7	10.8	97	27	3	1,003
Minimum	27	34	4.8	1.1	1.7	0.2	15	0	3.8	0.2	0.0	0.7	60	0.00	--	4.6	0.07	0.00	6.6	5	0	3.8	7.0	63	17	0	0
Number	29	36	36	36	36	36	36	23	36	36	36	36	36	33	--	36	32	11	36	36	16	39	39	39	36	36	39

pumping yields of up to 600 gpm have been developed from the major sand and gravel aquifers, which, however, may not be present everywhere in the delta.

Recharge to the aquifers in the delta area comes primarily from local precipitation. However, in the upper areas of the Skagit Valley, where the alluvium is more coarse than the fine-grained alluvium of the lower delta, recharge may come directly from the Skagit River. Aquifers in the lowlands are conservatively estimated to receive about 50,000 acre-feet of recharge annually.

Most ground water is discharged into the Skagit and Samish Rivers and their tributaries, but considerable amounts are lost to the atmosphere through evaporation and transpiration in the low-lying delta areas, where the water table is at or very near the land surface.

Samish Island is a water-short area. Most of the local precipitation runs off because of a thick cover of relatively impermeable glacial till. Some water does percolate, however, through breaks or permeable zones in the till and recharges the few aquifers that exist on the Island. These water strata have been tapped by several wells and supply sufficient water for present domestic use.

Quality

The quality of ground water in the Skagit-Samish Basins is variable. Water from some shallow wells is of poor quality and requires chemical treatment to remove objectionable iron and organic compounds before it can be used for domestic or many industrial purposes. In addition, ground water becomes increasingly saline towards the bay areas, and in some places along shorelines, fresh ground water cannot be obtained. However, salt water has not significantly encroached on most ground water sources. Quality data for water taken from wells in the western section of the Basins is shown in Table 4-6.

Ground waters generally may be classed as soft to slightly hard. The hardness of water from wells listed in Table 4-6 averaged 112 mg/l, although water from one well revealed a hardness of 320 mg/l.

High concentrations of iron in the ground water is a common problem in the Skagit-Samish Basins, although data in Table 4-6 do not indicate it. Iron concentrations in ground water in the vicinity of the Skagit River are usually higher than those in the rest of the Basin. Iron removal facilities have been included as part of the Anacortes water supply, which obtains ground water from two Ranney wells on the north bank of the Skagit River near Mount Vernon. The chemical and bacteriological qualities of water from these Ranney wells generally meet recommended quality standards for drinking water, and are of adequate quality for continued use.

TABLE 4-6. Ground water quality

Owner	Location code[a]	Depth (ft)	Date	Temperature (°F)	Silica (SiO_2) (mg/l)	Iron (fe) (mg/l)	Calcium (ca) (mg/l)	Magnesium (mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Bicarbonate (HCO_3) (mg/l)	Carbonate (CO_3) (mg/l)	Sulphate (SO_4) (mg/l)	Chloride (Cl) (mg/l)	Fluoride (F) (mg/l)	Nitrate (NO_3) (mg/l)	Orthophosphate (PO_4) (mg/l)	Dissolved solids (mg/l)	Hardness ($CaCO_3$) (mg/l)	Specific conductance (µmho)[c]	pH
Oscar Denton	33/3-5H1	112	11/21/49	—	—	0.05	—	—	—	—	358	0	20.0	34.0	0.2	18.0	—	—	320	708	—
H. A. Galbraith	33/4-33D1	—	11/21/49	—	—	0.03	—	—	—	—	136	0	2.0	6.0	0.2	0.0	—	—	94	233	—
N. Fortin	34/4-7P1	27	11/21/49	—	—	0.03	—	—	—	—	60	0	9.0	13.0	0.2	20.0	—	—	84	237	—
M. C. Turley	34/4-16F1	135	11/21/49	—	—	0.02	—	—	—	—	602	45	52.0	78.0	0.6	0.2	—	—	32	1,320	—
M. C. Holmgrem	34/4-33P1	103	11/21/49	—	—	0.03	—	—	—	—	194	0	14.0	22.0	0.2	0.0	—	—	154	385	—
L. H. Routan	35/3-11R1	197	11/21/49	—	—	0.03	—	—	—	—	322	0	16.0	216.0	0.3	1.1	—	—	142	1,180	—
Water Refineries, Inc.	35/4-32P	45	12/17/59	50	59	36.00	9.0	9.6	37.0	3.1	144	0	0.5	29.0	0.2	0.2	0.09	230	62	318	6.3
			5/18/60	52	—	—	—	—	—	—	131	0	—	—	—	—	—	—	65	295	6.2
State of Washington	35/5-8D1	231	12/17/59	52	32	0.44	23.0	11.0	23.0	3.2	142	0	0.7	27.0	0.2	0.0	0.36	181	101	315	7.7
(well 6)			5/18/60	51	—	—	—	—	—	—	145	0	—	—	—	—	—	—	104	309	7.9
Skagit Co. PUD No. 1	35/5-30M1	50	4/18/52	—	43	0.02	14.0	8.3	8.0	3.1	75	0	10.0	7.3	0.1	8.2	—	138	69	176	7.0

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

Future water requirements in the Basins will be determined primarily by the rate of growth of population, industry, and agriculture. Extensive surveys indicate that a substantial steady growth of these factors can be expected for the next 50 years. Details of this growth, projected at intervals to the year 2020, are presented in appropriate tables and charts in the following sections.

Basic water supplies pose no problem for the Basins through the year 2020. The Skagit River alone has a normal volume flow of 16,250 cfs (10,500 mgd), and the worst expected drought over a 20-year period would reduce this flow to not less than 4,600 cfs (2,967 mgd). The projected water needs for the entire Basins (116 mgd) are thus protected by a factor of 25 to 1. Further, the presently-owned water rights on the Skagit (290 mgd) are more than twice the total projected requirements for 2020. Most low population density rural regions that are beyond the service area of the major water supply systems have adequate ground and surface water supplies for the year 2020.

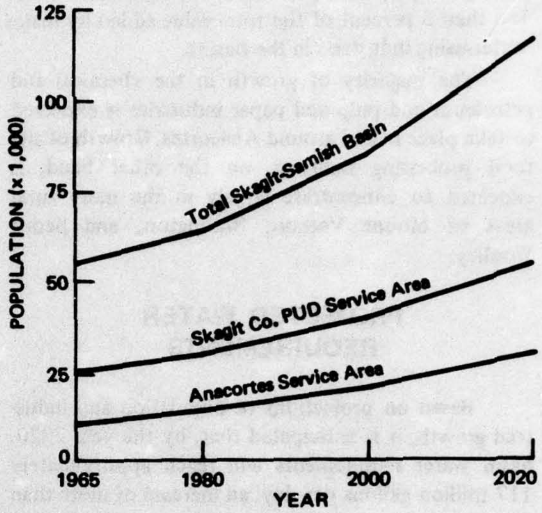


FIGURE 4-2. Projected population growth.

PROJECTED POPULATION GROWTH

The projected population in the Skagit-Samish Basins for the years 1965 through 2020 is shown graphically on Figure 4-2. This projection indicates that the 1965 population of the Basins (56,900) will increase approximately 16 percent (64,200 persons) by 1980, 56 percent (86,500 persons) by the year 2000, and 113 percent (118,000 persons) by 2020. The majority of the expected increase in population is expected to occur in and around the urban Anacortes area, in keeping with expected industrial expansion in that area.

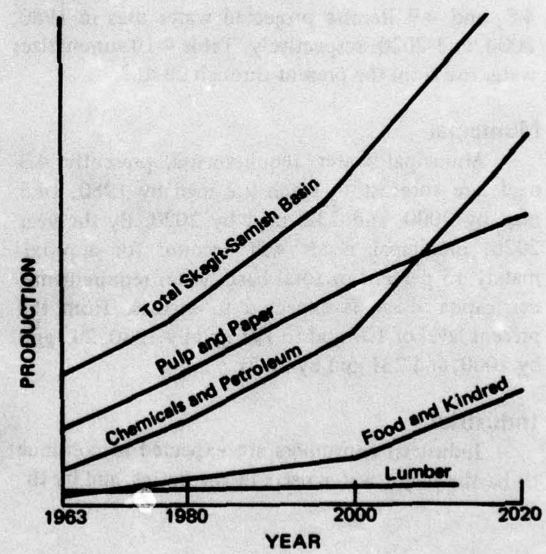


FIGURE 4-3. Relative production growth for major water-using industries.

PROJECTED INDUSTRIAL GROWTH

Production of the major water-using industries in the Skagit-Samish Basins is expected to increase approximately 270 percent between 1980 and 2020 in terms of dollar value to the Basins. As shown on Figure 4-3, the chemicals, petroleum, and food industries are expected to remain the major industrial forces in the Basins, and by 2020 should account for more than 94 percent of the total value added by major water-using industries. The pulp and paper industry is projected to increase moderatley through 1980, and then to decline slightly through 2020. Total timber harvest should remain at about the

present level, but usage will shift from lumber production to manufacture of pulp and plywood. By 2020, the pulp and paper industry will account for less than 3 percent of the total value added by major water-using industries in the Basins.

The majority of growth in the chemical and petroleum and pulp and paper industries is expected to take place in and around Anacortes. Growth of the food processing industry, on the other hand, is expected to concentrate largely in the more rural areas of Mount Vernon, Burlington, and Sedro Woolley.

PROJECTED WATER REQUIREMENTS

Based on projections of population and industrial growth, it is anticipated that, by the year 2020, basin water requirements will reach approximately 117 million gallons per day, an increase of more than 300 percent over present requirements. Figure 4-4 illustrates projected water needs in the two major service areas and in the Basins as a whole. Tables 4-7, 4-8, and 4-9 itemize projected water uses in 1980, 2000, and 2020, respectively. Table 4-10 summarizes water use from the present through 2020.

Municipal

Municipal water requirements, presently 4.3 mgd, are forecast to reach 9.2 mgd by 1980, 14.5 mgd by 2000, and 23.2 mgd by 2020. By the year 2020, municipal needs will account for approximately 15 percent of total basin water requirements. Per capita usage is expected to increase from the present level of 107 gpd to 191 gpd by 1980, 209 gpd by 2000, and 231 gpd by 2020.

Industrial

Industrial consumers are expected to continue to be the major water users in the Basins, and by th

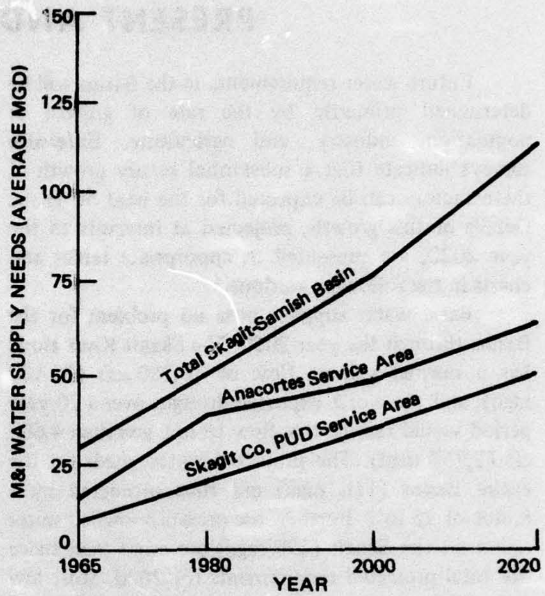


FIGURE 4-4. Location of projected water supply needs

year 2020 are forecast to require 81 percent of the total basin water needs. The present industrial water needs of 23 mgd are expected to increase 70 percent by 1980 and nearly 300% to 91 mgd by 2020. Industrial requirements are expected to be greatest in the Anacortes area, in keeping with projected growth trends. The paper manufacturing and refining industries in the Anacortes area are forecast to require about 55 percent of total basin needs.

Rural-Individual

Rural-individual requirements are forecast to reach only about 2 mgd by 2020, an increase over present requirements of 120 percent, but a decrease from 6 percent to less than 2 percent of total basin requirements.

TABLE 4-7. Projected water use (1980)

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Anacortes	13,000	2.5	3.5	—	—
Skagit County PUD No. 1 (Mount Vernon, Burlington, Sedro Woolley)	30,000	5.7	8.0	—	—
Darrington, Concrete, Lyman, Hamilton, and rural community systems	5,200	0.2	0.3	0.8	1.1
Subtotal	48,200	8.4	11.8	0.8	1.1
RURAL-INDIVIDUAL USE	16,000	—	—	1.1[a]	1.5
INDUSTRIAL USE					
Municipally supplied:					
Anacortes					
Paper and allied	—	11.4	12.5[c]	—	—
Petroleum	—	12.8	12.8	—	—
Chemicals	—	0.3	0.3	—	—
Food and kindred	—	0.5	0.8[b]	—	—
Naval Air Base (Whidbey Island)	—	1.5	2.0	—	—
Skagit County PUD No. 1					
Food and kindred	—	6.9	10.4[b]	—	—
Metals	—	2.5	3.8	—	—
Self-supplied:					
Food and kindred	—	2.5	3.7[b]	—	—
Stone, clay, glass	—	0.5	0.6	—	—
Subtotal	—	38.9	46.9	—	—
Total	64,200	47.3	58.7	1.9	2.6

[a]Based on assumed 70 gpcd and 100 percent of rural population to be served by ground water.

[b]150 percent of average.

[c]110 percent of average.

TABLE 4-8. Projected water use (2000)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Anacortes	20,000	4.2	5.9	—	—
Skagit County PUD No. 1 (Mount Vernon, Burlington, Sedro Woolley)	40,000	8.4	11.8	—	—
Darrington, Concrete, Lyman, Hamilton and rural community systems	9,200	0.4	0.6	1.5	2.1
Subtotal	69,200	13.0	18.3	1.5	2.1
RURAL-INDIVIDUAL USE	17,300	—	—	1.6[a]	2.2
INDUSTRIAL USE					
Municipally supplied:					
Anacortes					
Paper and allied	—	11.4	12.5[c]	—	—
Petroleum	—	22.5	22.5	—	—
Chemicals	—	0.7	0.7	—	—
Food and kindred	—	1.0	1.5[b]	—	—
Naval Air Base (Whidbey Island)	—	2.0	2.5	—	—
Skagit County PUD No. 1					
Food and kindred	—	13.8	20.7[b]	—	—
Metals	—	3.5	5.2	—	—
Self-supplied:					
Food and kindred	—	5.0	7.5[b]	—	—
Stone, clay, glass	—	1.0	1.2	—	—
Subtotal	—	60.9	74.3	—	—
Total	86,500	73.9	92.6	3.1	4.3

[a]Based on 90 gpcd and 100 percent of rural population served by ground water.

[b]150 percent of average.

[c]110 percent of average.

TABLE 4-9. Projected water use (2020)

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Anacortes	30,000	6.9	9.7	—	—
Skagit County PUD No. 1 (Mount Vernon, Burlington, Sedro Woolley)	55,000	12.7	17.8	—	—
Darrington, Concrete, Lyman, Hamilton, and rural community systems	15,500	1.0	1.4	2.6	3.6
Subtotal	100,500	20.6	28.9	2.6	3.6
RURAL-INDIVIDUAL USE	17,700	—	—	2.0[a]	2.8
INDUSTRIAL USE					
Municipally supplied:					
Anacortes					
Paper and allied	—	4.2	4.6[c]	—	—
Petroleum	—	40.0	40.0	—	—
Chemicals	—	1.4	1.4	—	—
Food and kindred	—	1.9	2.8[b]	—	—
Naval Air Base (Whidbey Island)	—	2.5	3.0	—	—
Skagit County PUD No. 1					
Food and kindred	—	25.3	38.0[b]	—	—
Metals	—	4.5	6.8	—	—
Self-supplied:					
Food and kindred	—	9.2	13.8[b]	—	—
Stone, clay, glass	—	2.2	2.5	—	—
Subtotal	—	91.2	113.0	—	—
Total	118,200	111.8	141.9	4.6	6.4

[a]Based on 110 gpcd and 90 percent of rural population served by ground water.

[b]150 percent of average.

[c]110 percent of average.

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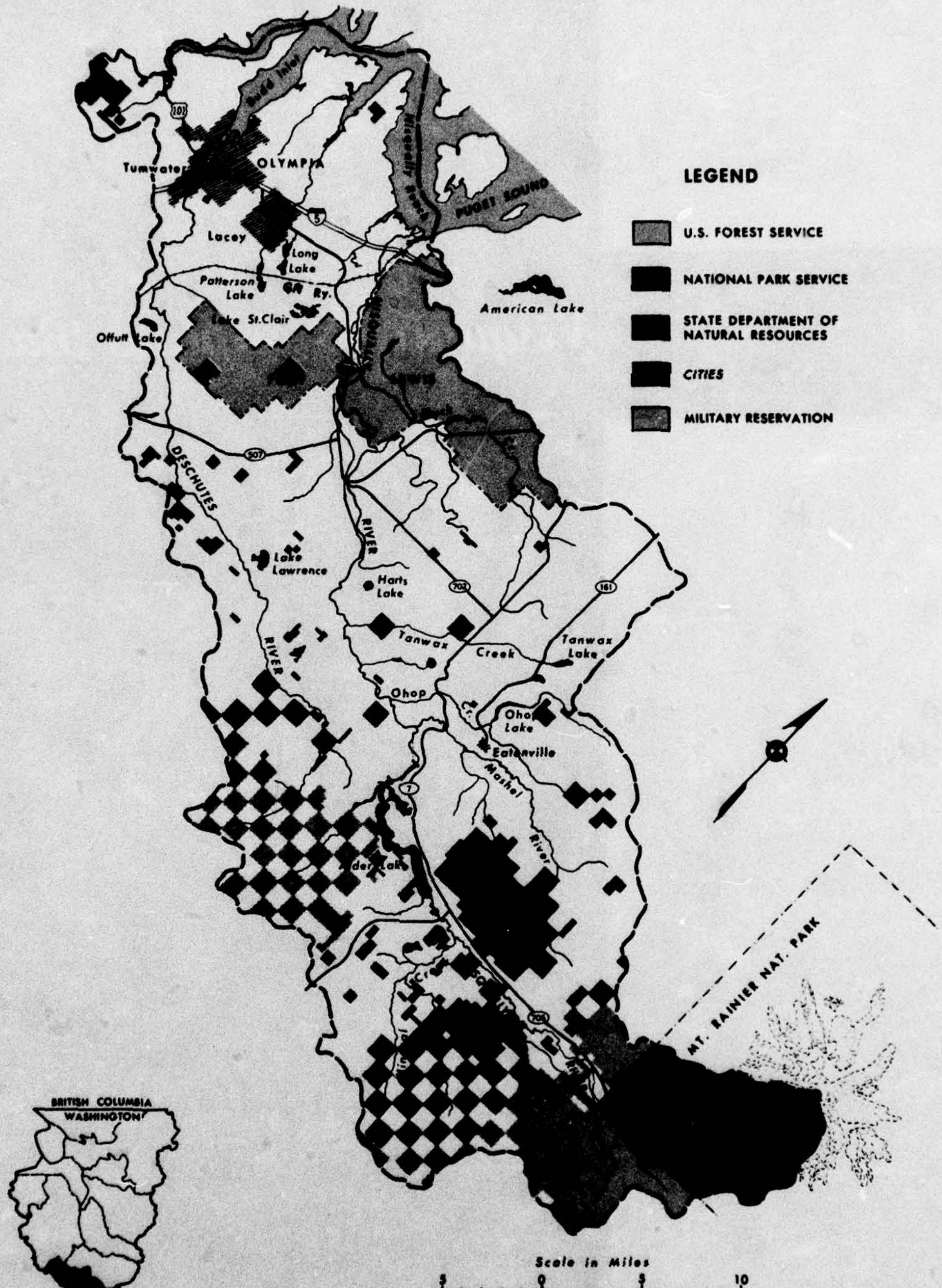


NISQUALLY -DESCHUTES BASINS

Figure 9—1 Land Ownership

NISQUALLY-DESCHUTES BASINS

INTRODUCTION

The Nisqually-Deschutes Basins, Figure 9-1, bounded by the Cascade Mountain Range on the east, by the Puyallup basin on the north, and by Puget Sound on the west, is the southernmost of the Puget Sound Area basins. It encompasses a land area of 1,044 square miles, primarily in Thurston County, and includes Olympia, the State Capitol, and the southwest portion of the Fort Lewis military reservation.

GEOGRAPHY

The outstanding physical feature of the *Nisqually-Deschutes Basins* is a broad glacial plain occupying the western portion of the basin. This plain comprises flatlands from 200 to 500 feet in elevation that include Chambers, Ruth, Smith, and Yelm Prairies. Low places in these prairies contain some rather large lakes, notably Chambers, Offut, Hicks, Long, Patterson, and Lawrence Lakes. The eastern portion of the basin includes the foothills and southwestern slope of Mount Rainier, watershed for the two major basin streams, the Nisqually and Deschutes Rivers.

The Nisqually River, fed by glaciers on the south side of Mount Rainier, flows northwest for over 80 miles before entering Puget Sound at Nisqually Flats, 10 miles northeast of Olympia. The Deschutes River heads in the hills east of Yelm and flows westerly across 35 miles of benchlands and prairies to empty into Budd Inlet, the southernmost arm of Puget Sound.

CLIMATE

Basin climate is characterized by moderate summers and wet, mild winters, with lower temperature and higher precipitation patterns recorded in the mountainous sector to the east. Total precipitation ranges from 38 inches annually in the lowlands to 120 inches in the mountains. Of this precipitation, only about 6 percent falls during the summer months of June, July, and August, while approximately 80 percent falls during October through March. There is very little variation in temperature in the lowland area. Daytime temperatures during the winter are usually 4.5° C to 10.0° C (40° to 50° F) with nighttime temperatures in the range of 30 - 40° F. Maximum temperatures are between 21° C (70° F) and 26.8° C (80° F) during the summer.

POPULATION

An estimated 68,933 persons (1965) live in the Nisqually-Deschutes Basins. Olympia, with a 1967 population of 20,830, in the State Capitol and county seat of Thurston County. Lacey and Tumwater are adjacent communities with populations of 7,650 and 4,450, respectively. Smaller towns such as Yelm, Eatonville, and Rainier in the nearby farming areas have populations of fewer than 900 persons each. The remainder of the population resides on military reservations, primarily Fort Lewis.

ECONOMY

Forest products are the mainstay of basin economy. However, metal craft, can manufacturing, boat building, cold storage, and meat packing are of marked importance today and give the area a diversified commercial base. The Olympia Brewing Company, located in the adjacent town of Tumwater, also has a favorable impact on Basin economy.

Government, however, remains the leading employer in Thurston County, accounting for almost 36 percent of total employment in 1963. Between 1950 and 1960, government employment in Thurston County increased by 46.6 percent. The manufacturing sector also plays a leading role, but increases in employment have been gradual, 2.7 percent in the 1950 to 1960 decade and 3.10 percent in the 1954 to 1964 decade.

The Port of Olympia, comprising over 72 acres surrounding Budd Inlet, is equipped to handle cargo from both ocean vessels and local water freight. It also serves as an export log receiving, handling, and rafting site for the local lumbering industry. Industrial plants occupy approximately half of the port property.

Livestock raising, located mostly in the central and western portions of the basin, is the most common and valuable farm industry, though dairying, berry growing, and poultry raising also play an important part in the economy of the basin.

Fort Lewis contributes to the basin employment and economy.

LAND USE

Land use in the basin ranges from intense residential and industrial areas on the southern shores of Puget Sound, through dairying and farming on the prairies, to heavy growths of timber in the southern sector. Forestland predominates and accounts for 85 percent of total basin land area. Cropland, devoted mainly to feed crops to support the dairy and livestock industry, occupies the second largest land area of approximately 6 percent. Urban areas comprise less than 3 percent of total basin land area. Land use in the area is summarized in table 9-1.

TABLE 9-1. General land use.

Use	Acres
Forestland	508,000
Cropland	46,000
Rangeland	43,000
Other land (high, barren)	20,000
Urban buildup	19,000
Inland water	10,000
Total land and inland water	646,000

Source: Appendix III, Hydrology.

PRESENT STATUS

Present water sources and systems are adequate to supply all basin consumers, and usable sources of ground and surface water far exceed the expected water requirements through the turn of the century.

WATER USE

Total water use in the Basin by approximately 70,000 persons and numerous industries averages 7.6 mgd, the greater share of which is supplied by various ground sources. Water use is rather evenly divided between municipal, industrial, and rural-individual users, with municipal use accounting for approximately 55 percent of the total. Water consumption for the basin is detailed in Table 9-2, except 4 existing County water districts not now providing service.

Municipal

Municipal water use currently is 4.08 million gallons per day, and accounts for 55 percent of total Basin water consumption. The city of Olympia, serving 22,632 persons, is the largest single water user. Per capita use for Olympia is 124 gpd. Tumwater uses 0.6 mgd in serving 4,450 persons, accounting for a per capita use of 135 gpd. The major rural communities, consisting of 6,645 persons, use 1.05 mgd, a per capita use of 158 gpd.

Industrial

Industrial consumers account for about 29 percent of the total water use in the basin, averaging more than 2 mgd. Largest industrial user in the basin is the Olympia Brewing Company at Tumwater, which uses an average of 1.4 mgd. Several food plants and plywood manufacturers in Olympia together use about 0.35 mgd.

Rural-Individual

About 22,900 persons living in rural areas use 1.3 mgd of water, one-third of the basin's total water consumption and an average per capita use of about 57 gpd.

WATER SUPPLIES

Ground water sources supply about 87 percent (6.6 mgd) of the total water used in the basin. Surface water, from small creeks, supplies 1.0 mgd. The Nisqually and Deschutes Rivers are potentially important as sources of supply for both municipal and industrial purposes, although they are not presently used.

TABLE 9-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Surface water usage (mgd) Maximum daily	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Ground water usage (mgd) Maximum daily
MUNICIPAL USE							
Olympia	22,632	—	—	—	2.80	4.70	6.70
McKinley Water Co., Inc.	(1,000)	—	—	—	(0.14)	(0.27)	(0.41)
West Conger Water Supply Co.	(63)	—	—	—	(0.01)	(0.02)	(0.02)
Paradise	4,500	0.20	0.23	0.26	—	—	—
Huntamer-Water Service, Inc.	4,500	0.10	0.20	0.30	0.20	0.90	1.70
Tumwater	4,460	—	—	—	0.60	1.20	1.80
Longmire	1,200	0.08	0.10	0.13	—	—	—
Eatonville	1,000	0.20	0.70	1.20	—	—	—
Yelm	795	—	—	—	0.10	0.20	0.25
Rainier	300	—	—	—	0.01	0.02	0.03
Other rural community systems	6,645	0.02	0.03	0.04	1.03	1.64	2.11
Subtotal	46,022 [c]	0.60	1.26	1.93	3.48	8.66	12.59
RURAL-INDIVIDUAL USE [a]	22,911	0.13	0.18	0.26	1.13	1.60	2.26
INDUSTRIAL USE							
Municipally supplied:							
Olympia							
Food and kindred		—	—	—	0.12	0.12	0.12
Lumber and wood		—	—	—	0.40	0.50	0.60
Yelm							
Food and kindred		—	—	—	0.02	0.02	0.02
Self-supplied:							
Food and kindred		—	—	—	1.40	1.70	2.00
Stone, clay, glass		0.24	0.24	0.24	—	—	—
Other sources;		—	—	—	0.04	0.05	0.06
Subtotal		0.24	0.24	0.24	2.00	2.40	2.80
Total[b]	68,933	1.00	1.70	2.40	6.60	12.70	17.60

[a] Estimated 90 percent of rural individual population supplied by ground water.

[b] Figures are rounded.

[c] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

Municipal

Municipal consumers in the Basin use an average of 4.08 mgd, more than 85 percent of which is supplied from ground water sources. Olympia, largest municipal supplier in the Basin, provides approximately 22,500 persons an average of 2.80 mgd from McAllister Springs near the Nisqually River. The city of Lacey recently purchased the Huntamer Water Service, Inc., to create a municipal water department. This water supply is a group of small to medium sized vertical wells located in and around the city. The city of Tumwater, much the same as Lacey, uses ground water from wells located near the Deschutes River. The Olympic Brewery, at Tumwater, uses self-sup-

plied ground water from artesian wells in the Deschutes Basin. Tumwater and Yelm and other rural communities supply approximately 17,000 municipal consumers with about 1.95 mgd, also drawn from ground sources.

The community of Eatonville and the Federally owned park communities of Paradise and Longmire serve an estimated 6,700 persons from surface sources, however, Eatonville is converting to infiltration wells along the river.

Industrial

Industrial users are supplied an average of 2.24 mgd, approximately 90 percent of which is drawn from ground water sources. At Tumwater (photo 9-1), the Olympia Brewing Company, largest industrial consumer in the basin, draws its average daily supply of 1.4 mgd from artesian wells. The municipalities of Olympia and Yelm supply a total of 0.54 mgd to industrial users.

Rural-Individual

Approximately 22,900 rural-individual consumers are supplied 1.3 mgd from individual and small community distribution systems, of which an estimated 90 percent is drawn from ground sources.

WATER RIGHTS

The Nisqually-Deschutes Basin has a total of 716 recorded water rights; of these, 447 are surface and 269 are ground (1966-1967).

The total surface water prime right appropriations are 3,875 mgd. Power generation, industrial and irrigation are the largest surface water users in the basin with rights for 3,640, 160 and 43 mgd, respectively. The remaining water rights (41 mgd) are used by individual and community domestic, municipal and fish propagation. Supplemental rights have been used for 11 mgd in the above catagories. Reservoir storage rights allow a total annual retention of 210,474 acre-feet.

As of April 30, 1967, applications for water rights with a potential of 1,034 mgd were on file with the Department of Water Resources.

Photo 9-1 Tumwater and Olympia, as well as most of the basin, rely mainly on ground water sources.

Diversion restrictions for low-flow periods have been imposed on many streams. Eight streams, including the Deschutes River proper, have been closed to further consumptive appropriations.

Ground water used in the basin amounts to a prime right total of 85 mgd with irrigation, individual and community domestic and industrial being the largest users. Supplemental rights amounting to 0.6 mgd have been issued in conjunction with the above catagories.

Applications indicate the potential of 2 mgd additional being developed within the basin. Table 9-3 lists water rights in the basin.

TABLE 9-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	22.7	12.1	160.5
Ground water	11.7	34.1	14.5
Total[a]	34.4	46.2	175.0

[a]About 3,715 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

SURFACE WATER

Surface water sources in the basin, including streams, impoundments, and lakes, are plentiful and are capable of supplying sufficient water to meet anticipated future needs, although they presently supply less than 15 percent of the basin water needs.

Quantity Available

Streams. The natural flow of the Nisqually River is affected by regulation at Alder and LaGrande reservoirs. However, adjusted flows for the river near McKenna indicate a mean annual discharge of 1,758 cfs during the 30-year period 1931 through 1960. The maximum discharge (2,540 cfs) occurred in 1956 and was 144 percent of the 1931 through 1960 mean. The minimum runoff occurred in 1944 and was only 59 percent of the long-term 30-year mean. Another discharge station on the Nisqually near National measures approximately 70 percent of the runoff from this stream. During the 23-year period 1942 through 1965, the mean annual discharge was 778 cfs, with recorded high and low flows of 11,000 cfs and 108 cfs, respectively.

The natural runoff pattern of the Nisqually River consists of two distinct peak periods each year: one from abundant winter precipitation falling mainly in the form of rain at lower elevations, and a second during the spring from the melting of accumulated snowpacks in the high country. The low-flow period occurs in late summer, but large quantities of glacial melt water from the slopes of Mount Rainier augment the flows during the warm months. The summer base flow is usually about 400 cfs.

A discharge station near Olympia measures about 99 percent of the runoff from the Deschutes River. The mean annual runoff was 390 cfs for the adjusted period of record. Since 1946, when record collection was begun at this station, the maximum discharge recorded was 6,650 cfs and the minimum was 279 cfs. Records from a gaging station at Rainier on the upper headwaters of the Deschutes indicate a mean annual discharge of 267 cfs, based on a period of record from June 1949 through September 1965.

Runoff from the Deschutes River displays the same pattern as other rain-fed streams of Puget Sound. A period of high flow occurs during the winter months and minimum flows, enhanced primarily from ground water discharges, occur during the months of August and September. The summer base flow of this stream is about 100 cfs.

The USGS has calculated low-flow frequencies for the Nisqually and Deschutes Rivers using flow data compiled at 13 discharge stations during the 18-year period April 1946 through March 1964. The estimated minimum flows that may be expected to occur during any 7-day and 30-day period at four of these stations for recurrence intervals of 5, 10, and 20 years are shown in table 9-4.

TABLE 9-4. Low-flow frequency.

Discharge station	Recurrence interval (years)	7-day low flow (cfs)	30-day low flow (cfs)
Deschutes River near Olympia	5	85.0	89.0
	10	80.0	83.0
	20	75.0	79.0
Woodland Creek near Olympia	5	9.9	10.9
	10	8.8	9.7
	20	8.0	8.9
Nisqually River near National	5	202.0	250.0
	10	178.0	213.0
	20	156.0	188.0
Nisqually River near McKenna	5	445.0	560.0
	10	405.0	500.0
	20	375.0	455.0

Dams and Impoundments. The two major reservoirs in the basin are located on the Nisqually River and are operated by the city of Tacoma for power generation. The Alder Reservoir has 232,000 acre-feet of storage, and immediately downstream from Alder Dam is LaGrande Reservoir, with a storage capacity of 2,700 acre-feet. There is no significant storage development on the Deschutes River.

Lakes. A number of lakes of significant size and storage capacity provide an indication of the abundance of water resources. Although the Basin lakes are presently used only for recreation, they are a resource that provides natural storage for substantial quantities of water.

TABLE 9-5. Surface water quality.

Item	Discharge (cfs)	mg/l Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (μmho)	mg/l Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	mg/l Dissolved oxygen	Oxygen saturation (%)	mg/l Total	Noncarbonate	Coliform (MPN)
DESCHUTES RIVER NEAR RAINIER																			JULY 1959 THROUGH AUGUST 1962								
Maximum	744	91	12.0	3.2	7.4	0.9	54	0	3.4	12.0	0.1	0.7	131	0.13	...	23.0	0.48	0.02	7.7	25	5	17.2	11.9	106	43	1	930
Mean	...	67	9.0	2.1	5.1	0.5	40	0	2.0	5.8	0.1	0.4	88	0.05	...	19.1	0.17	0.01	...	...	...	10.2	10.5	96	31	0	170
Minimum	36	46	5.5	1.0	3.1	0.2	27	0	1.0	2.0	0.0	0.1	56	0.00	...	16.0	0.03	0.00	6.9	5	0	5.9	8.0	68	19	0	0
Number	21	21	21	21	21	21	21	8	21	21	21	21	21	21	...	21	21	4	21	21	4	21	21	21	21	21	21
DESCHUTES RIVER AT TUMWATER																			OCTOBER 1962 THROUGH PRESENT								
Maximum	1,750	89	12.0	3.8	7.1	1.2	52	0	3.8	11.0	0.1	1.6	122	0.12	...	25.0	0.88	0.03	7.8	20	30	20.1	11.7	118	46	3	2,400
Mean	...	74	9.0	2.7	5.5	0.9	41	0	3.2	6.6	0.1	1.1	95	0.07	...	20.7	0.36	0.01	...	...	...	10.1	10.7	97	34	1	646
Minimum	175	54	5.5	1.7	3.8	0.4	25	0	2.2	2.5	0.0	0.6	59	0.00	...	16.0	0.16	0.00	6.6	5	0	4.0	8.7	88	20	0	0
Number	6	15	15	15	15	15	15	15	15	15	15	15	15	12	...	15	11	6	15	15	10	16	16	16	15	15	16
NISQUALLY RIVER NEAR MCKENNA																			FEBRUARY 1955 THROUGH SEPTEMBER 1955								
Maximum	3,390	48	4.8	1.2	3.0	0.7	24	...	2.5	1.5	0.2	1.2	49	...	...	14.0	0.11	0.05	7.2	30	...	...	...	...	17	0	...
Mean	...	48	4.8	1.1	2.9	0.6	23	...	2.3	1.3	0.1	0.7	49	...	...	12.0	0.06	0.05	...	...	...	...	...	...	17	0	...
Minimum	968	47	4.8	1.0	2.8	0.6	22	...	2.1	1.0	0.1	0.2	48	...	...	10.0	0.02	0.05	7.1	0	...	...	...	...	16	0	...
Number	2	2	2	2	2	2	2	...	2	2	2	2	2	...	...	2	2	2	2	2	...	...	...	...	2	2	...
NISQUALLY RIVER AT MCKENNA																			JULY 1959 THROUGH PRESENT								
Maximum	4,160	61	7.5	2.4	4.2	1.3	41	0	5.2	2.8	0.3	0.9	79	0.19	...	22.0	4.40	0.08	7.5	25	25	20.0	12.8	117	28	0	2,400
Mean	...	47	5.7	1.4	3.1	0.6	27	0	2.6	1.6	0.1	0.3	55	0.04	...	14.8	0.48	0.02	...	...	...	9.5	11.2	101	20	0	247
Minimum	50	37	3.5	0.8	2.3	0.3	18	0	1.4	0.0	0.0	0.0	37	0.00	...	12.0	0.09	0.00	6.2	0	0	4.8	8.6	90	12	0	0
Number	29	37	37	37	37	37	37	24	37	37	37	37	37	33	...	37	32	11	37	37	16	37	37	36	37	37	37

Quality

The quality of water in the Nisqually and Deschutes Rivers has been measured since July 1959. Table 9-5 lists data from these measurements.

Physical. The temperature of the Nisqually and Deschutes rivers is relatively low. A maximum temperature of 20.0° C (68° F) has been recorded for the Nisqually at McKenna and a maximum of 20.1° C (68.2°F) has been recorded for the lower Deschutes.

During periods of glacial melt, the Nisqually River transports considerable quantities of sediment. The concentration of suspended sediment above Alder Lake ranges from 1 to 60,000 ppm, and data obtained at McKenna during 1965 and 1966 indicate that the river may transport as much as 250,000 to 300,000 tons of suspended sediment during a year of normal runoff. However, the majority of the sediment is deposited in Alder Lake. Similar data for the Deschutes River near east Olympia indicate that the Deschutes may transport an average of 30,000 tons annually.

Turbidity values are usually less than 15 JTU in the Nisqually and 10 JTU in the Deschutes, though maximum value of 25 JTU has been recorded for the Nisqually at McKenna a maximum of 30 JTU has been recorded for the Deschutes at Tumwater.

Chemical. Water of the Nisqually and Deschutes Rivers is soft, low in dissolved solids, and high in dissolved oxygen concentrations. Both streams, however, contain significant amounts of iron, particularly during periods of high flow. Iron concentrations in the Nisqually River average 0.48 mg/l, with a maximum of 4.40 mg/l having been recorded. Surface water in the headwaters of the Deschutes River near Rainier is low in iron, but downstream, near the outlet at Tumwater, iron concentrations are high, averaging 0.36 mg/l with a recorded maximum of 0.88 mg/l.

Bacteriological. Most of the samples collected from the Nisqually River at McKenna reveal coliform density MPN values of less than 100, though a maximum MPN of 2,400 was recorded. Coliform counts on the lower Deschutes at Tumwater average slightly higher than 646 MPN. Upstream on the Deschutes near Rainier, most MPN values are less than 100, but occasional samples reach as high as 930 MPN.

GROUND WATER

Ground water resources in the basin are plentiful, and though ground water presently supplies more than 85 percent of all water used in the basin, adequate reserves are available for future use. However, because ground water sources are particularly susceptible to contamination, and will become increasingly so as the basin becomes more urbanized, treatment plants may have to be constructed, or remote sources developed, to ensure a water supply of adequate quality.

Quantity Available

Plentiful supplies of usable ground water are available in the basin, particularly in the flood plain of the Nisqually River, and, to a lesser extent, on the Deschutes flood plain.

Recessional outwash, which covers most of the lowlands, is the most important aquifer in the basin, and moderate to large supplies of water can be drawn from this material. However, it is susceptible to contamination in urban areas because of its stratigraphic position. Till, a concrete-like mixture of clay, silt, sand, pebbles, cobbles, and boulders, is quite common and supplies many individual consumers with water for domestic use, though it is not an important aquifer in the basin.

Practically all aquifers in the basin are recharged by precipitation, and may receive as much as 200,000 acre-feet of recharge in an average year.

Quality

Most ground water in the basin is quite soft, low in dissolved solids, and of generally good quality. The concentrations of hardness indicators and dissolved solids are usually less than 60 mg/l and 150 mg/l, respectively. Concentrations of silica usually range from 20 to 40 mg/l. However, objectionable concentrations of iron occur locally, primarily in shallow aquifers that underlie the Nisqually flood plain, and highly mineralized ground water is common near Puget Sound where fresh-water aquifers contain traces of salt water. Table 9-6 shows ground water quality data for selected wells in the basin.

TABLE 9-6. Ground water quality.

				(mg/l)											
Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids	Hardness ($CaCO_3$)	Specific conductance (µmho)[c]	pH
Charles McPheil	16/3-22A2	2/8/61	48	48	0.26	26.0	3.7	25.0	2.0	0.2	0.39	186	80	249	7.7
S. R. White	16/4-5D1	12/15/60	49	50	0.23	21.0	12.0	10.0	2.5	0.1	0.26	163	100	223	7.4
George Lenz	18/2-35Q1	11/28/60	49	31	0.15	10.0	4.5	5.1	1.3	0.6	0.26	88	44	110	7.5
A. S. Andrews	18/4-10Q1	11/28/60	49	33	0.50[d]	16.0	6.3	6.4	2.9	0.1	0.49	117	66	160	7.8
J. M. Hales	17/2-19J5	2/12/52	51	21	2.00[d]	7.8	3.4	4.7	1.6	9.4		75	33	97	7.0
City of Yelm	17/2-19N1	11/12/59	50	23	0.25	9.0	2.9	4.6	1.0	5.0	0.11	75	34	101	6.7
Gilbert Roehr	17/2-29L4	2/12/52	51	21	1.20	11.0	5.7	6.1	2.0	4.7		103	51	129	7.3
Thurston County Public Utilities Dist. No. 1	18/1W-15H1	11/13/59	52	45	0.02	12.0	4.6	5.5	1.7	0.3	1.00	104	49	126	7.3
L. S. Huntamer	18/1W-21D3	4/20/58	51	35	0.06	6.4	5.4	5.2	2.0	6.6	0.14	88	38	111	7.3
City of Olympia	18/2W-24P1	12/30/44		34	0.25[d]	8.0	9.1	6.3	1.7	0.2		104	57	136	
Johnson Point Community Corp.	19/1W-4D	12/10/60	47	32	0.11	17.0	17.0	9.7	2.0	0.3	0.05	155	114	161	7.2
Coopers Point Water Co.	19/2W-9R1	11/12/59	52	46	0.62	14.0	2.9	20.0	1.9	0.8	2.20	143	47	192	7.2

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

The principal factors that will determine future water demand in the Nisqually-Deschutes Basin are population increase and increased use by processing industries. The major industry determined by the Task Force is food and kindred products. In the interim, since the Task Forces' projections, conditions of growth and change have altered the concepts of the M&I Committee toward population and industrial growth in the Nisqualley-Deschutes Basin. It is apparent that a new State college, an aggressive and well-supported Port District for industrial development, and a municipal water department in Olympia which has experienced in a few short years, a per capita increase in water consumption from a level experienced by smaller towns and communities to a per capita level experienced by the larger Puget Sound municipalities, such as Tacoma, Bellingham, and Mountlake Terrace, provided the Committee with adequate reasons to revise the projected population and industrial growth upward.

Not only industrial demands but also domestic use is projected to create more than a nominal increase in demand on water supplies.

PROJECTED POPULATION GROWTH

Figure 9-2 shows the projected population growth in the Basin from 1967 through 2020. The 1967 population 70,100 will increase about 54 percent to 74,900 by 1980, about 169 percent to 104,500 by the year 2000, and 312 percent to 146,500 by 2020. Most of the increase is expected to occur in and around the Olympia urban area. Increased need for local and State government services and educational services, and industrial growth of the Port of Olympia and Nisqually Flats area, will account for most of the added population.

PROJECTED INDUSTRIAL GROWTH

Production growth in the Nisqually-Deschutes Basin (Figure 9-3) as measure by value-added will increase 350 percent from the present to 2020.

Major industrial activity to the year 2020 will be food processing, with brewing the largest single contributor. As shown, this industry by then will account for more than three-fourths of the total value

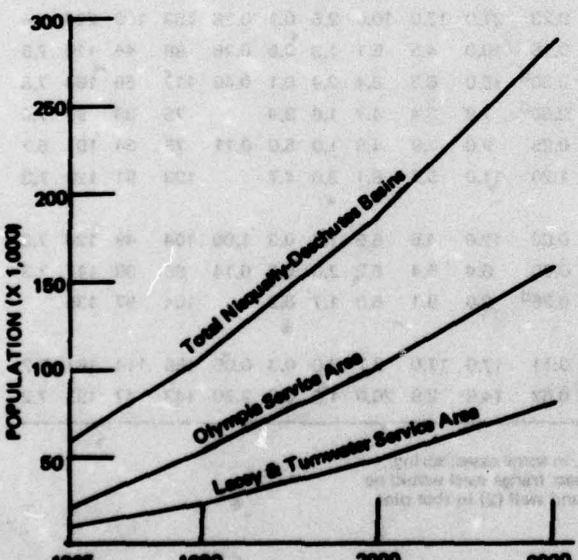


FIGURE 9-2. Projected population growth (by Task Force and Thurston County Planning Commission).

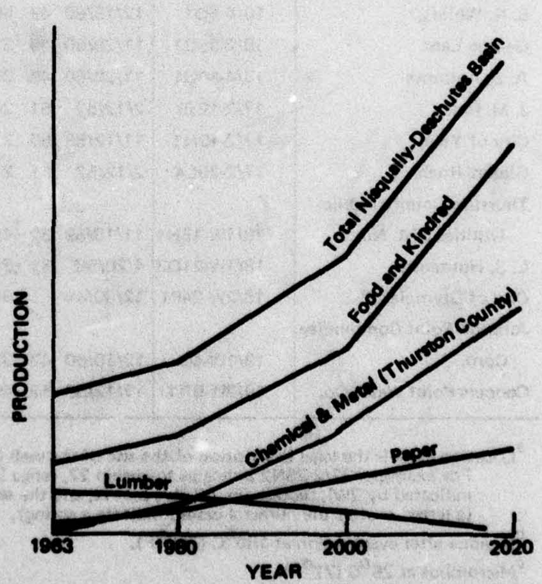


FIGURE 9-3. Relative production growth for major water-using industries.

added by major water-using industries. The prediction assumes that lumber production will decline, but that the decline will be made up by a rise in activities in the chemical and metals and pulp and paper industries, also major water users.

PROJECTED WATER REQUIREMENTS

Total water requirements in the Basin are expected to reach 88 mgd by the year 2020, an increase of about 878 percent over present requirements. Ground water sources will supply 97 percent of the projected water needs. Tables 9-7, 9-8, and 9-9 itemize projected water use in 1980, 2000, and 2020, respectively. Table 9-10 summarizes water use from the present through 2020.

Municipal

Municipal water requirements are projected to reach an annual daily average of 17.3 mgd by 1980, 33.2 mgd by 2000, and 54.0 mgd by 2020. Per capita municipal use is expected to rise from 89 gpd at present to 703 gpd in 1980, 205 gpd in 2000, and 207 gpd in 2020. These projected use figures, higher than most of the basins in the Study Area, are based on data from the city of Olympia Water Department. Because future municipal use in the Basin will occur mainly in Olympia service area, and because a considerable increase in water consumption is projected for other municipal systems in the Basin, these per capita figures appear reasonable.

Industrial

Industrial water needs annually average 2.2 mgd at present. Demand is expected to increase to 8.1 mgd by 1980, to 16.8 mgd by 2000, and to 26.0 mgd by 2020. Industries will use 25 to 35 percent of the total water needs in the Basin. Until about 1980 or 1985, ground water will supply most needs of industries. After that, surface water development could begin to supply at least part of the needs.

Rural-Individual

Rural-individual water requirements, presently averaging 1.26 mgd annually, will increase to 3.2 mgd by the year 2020. This increase is substantially less than increases in other use categories; rural-individual needs which now comprise 16 percent of the total demand, will amount to less than 4 percent of total water requirements by 2020.

TABLE 9-7. Projected water use (1980)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Olympia	51,100	—	—	10.70	13.80
Tumwater	11,600	—	—	2.23	2.88
Lacey	11,600	—	—	2.23	2.88
Eatonville, Yelm, Rainier, Longmire, Paradise and rural community systems	11,000	0.4	0.6	1.70	2.40
Subtotal	85,300	0.4	0.6	16.90	23.40
RURAL-INDIVIDUAL USE	22,500	—	—	1.60[a]	2.20
INDUSTRIAL USE					
Olympia					
Chemical				5.00	6.00
Food and kindred	—	—	—	0.15[b]	0.23[c]
Lumber and wood	—	—	—	0.30[e]	0.33[f]
Yelm					
Food and kindred				0.03[b]	0.04[c]
Self-supplied:					
Food and kindred	—	—	—	1.80[b]	2.30[d]
Stone, clay, glass	—	0.4	0.6[c]	—	—
Paper and allied[g]	—	—	—	0.40	0.45
Subtotal	—	0.4	0.6	7.70	10.40
Total[h]	107,800	0.8	1.2	26.20	36.50

[a] Based on 70 gpcd and 100 percent of rural individual population served by ground water by 1980.

[b] Determined as a percent of 1965 water use by using growth factors of 1.25 (1965-1980), 1.98 (1980-2000), and 1.90 (2000-2020).

[c] 150 percent of average.

[d] 125 percent of average (brewery demand which is more evenly distributed between average and maximum).

[e] Lumber and wood projected to decline to year 2020. Water use based on growth factors of 0.8, 0.6, 0.4 for 1965-80, 1980-2000, 2000-2020.

[f] 110 percent of average.

[g] Projected for basin on basis of economic projection. 1965 water use for paper and allied not known—guessed to be about 0.2 mgd.

[h] Figures are rounded.

TABLE 9-8. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Olympia	100,700	—	—	21.60	27.86
Tumwater	23,400	—	—	4.31	5.56
Lacey	23,400	—	—	4.31	5.56
Eatonville, Yelm. Rainier, Longmire, Paradise and rural community systems	14,500	0.6	0.8	2.40	3.40
Subtotal	162,000	0.6	0.8	32.60	42.40
RURAL-INDIVIDUAL USE	26,000	—	—	2.30 [a]	3.30
INDUSTRIAL USE					
Olympia					
Chemical				11.00	13.00
Food and kindred	—	—	—	0.30 [b]	0.45 [c]
Lumber and wood	—	—	—	0.18 [e]	0.19 [f]
Yelm					
Food and kindred	—	—	—	0.06 [b]	0.10 [c]
Self-supplied:					
Food and kindred	—	—	—	3.60 [b]	4.50 [d]
Stone, clay, glass	—	0.9	1.3 [c]	—	—
Paper and allied [g]	—	—	—	0.80	0.90 [f]
Subtotal	—	0.9	1.3	15.40	14.10
Total [h]	188,000	1.5	2.1	50.80	64.80

[a] Based on 90 gpcd and 100 percent of rural individual population served by ground water by 1980.

[b] *Determined as a percent of 1965 water use by using growth factors of 1.25 (1965-1980), 1.98 (1980-2000), and 1.90 (2000-2020).*

[c] 150 percent of average.

[d] 125 percent of average (brewery demand which is more evenly distributed between average and maximum).

[e] *Lumber and wood projected to decline to year 2020. Water use based on growth factors of 0.8, 0.6, 0.4 for 1965-1980, 1980-2000, 2000-2020.*

[f] 110 percent of average.

[g] *Projected for basins on basis of economic projection. 1965 water use for paper and allied not known—guess to be about 0.2 mgd.*

[h] *Figures are rounded.*

TABLE 9-9. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
MUNICIPAL USE					
Olympia	157,400	—	—	40.00	51.6
Tumwater	40,000	—	—	7.05	9.09
Lacey	40,000	—	—	7.05	9.09
Eatonville, Yelm, Rainier, Longmire, Paradise and rural community systems	21,200	0.8	1.1	4.10	5.80
Subtotal	259,600	0.8	1.1	58.20	75.60
RURAL-INDIVIDUAL USE	29,300	—	—	3.20	4.50
INDUSTRIAL USE					
Olympia					
Chemical				15.00	18.00
Food and kindred	—	—	—	0.60	0.90
Lumber and wood	—	—	—	0.10	0.11
Yelm					
Food and kindred	—	—	—	0.11	0.17
Self-supplied:					
Food and kindred	—	—	—	6.80	8.60
Stone, clay, glass	—	2.2	3.3	—	—
Paper and allied	—	—	—	1.20	1.30
Subtotal	—	2.2	3.3	23.8	29.1
Total	287,900	3.0	4.4	85.2	109.2

[a]Based on 110 gpcd and 100 percent of rural individual population served by ground water by 1980.

[b]Determined as a percent of 1965 water use by using growth factors of 1.25 (1965-1980), 1.98 (1980-2000), and 1.90 (2000-2020).

[c]150 percent of average.

[d]125 percent of average (brewery demand which is more evenly distributed between average and maximum).

[e]Lumber and wood projected to decline to year 2020. Water use based on growth factors of 0.8, 0.6, 0.4 for 1965-1980, 1980-2000, 2000-2020.

[f]110 percent of average.

[g]Projected for basin on basis of economic projection. 1965 water use for paper and allied not known—guessed to be about 0.2 mgd.

[h]Figures are rounded.

TABLE 9-10. Summary of projected water needs

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total water usage (mgd) Average daily	Total water usage (mgd) Maximum monthly
Municipal	1965	46,000	0.6	1.3	4.7	8.7	5.3	10.0
	1980	85,300	0.4	0.6	16.9	23.9	17.3	24.5
	2000	162,000	0.6	0.8	32.6	42.4	33.2	43.2
	2020	258,600	0.8	1.1	58.2	75.6	59.0	76.7
Industrial	1965	–	0.2	0.2	2.0	2.4	2.2	2.6
	1980	–	0.4	0.6	7.7	10.4	8.1	11.0
	2000	–	0.9	1.3	15.9	19.1	16.8	20.4
	2020	–	2.2	3.3	23.8	29.1	26.0	32.4
Rural-Individual	1965	22,900	0.1	0.2	1.1	1.6	1.2	1.8
	1980	22,500	–	–	1.6	2.2	1.6	2.2
	2000	26,000	–	–	2.3	3.3	2.3	3.3
	2020	29,300	–	–	3.2	4.5	3.2	4.5
Totals	1965	68,900	0.9	1.7	7.8	12.7	8.7	14.4
	1980	107,800	0.8	1.2	26.2	36.5	27.0	37.7
	2000	188,000	1.5	2.1	50.8	64.8	52.3	66.9
	2020	287,900	3.0	4.4	85.2	109.2	88.2	113.6

Note: All figures are rounded.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 88 mgd by the year 2020. This is an increase of 84 mgd over the 1965 average use. Optimum or peak water requirements will be almost two times this average or nearly 156 mgd. Tables 2-12 or 2-13, the Area Plans, summarize the Basin's annual average and optimum requirement. Table 9-11, M&I Water Supply Needs, reviews the needs of the major water systems in the Basin.

Nisqually-Deschutes Basin not only has adequate surface water but also has very substantial ground water aquifers. At present, ground water supplies 87 percent of all water used in the basins and further development to satisfy future needs is possible.

The city of Olympia presently draws its water from McAllister Spring source near the Nisqually River. Present development at the sources is capable of supplying 21 mgd. With additional transmission facilities, this could be expanded to 30 mgd.

The city of Lacey having recently purchased the local water system can develop it to meet the future needs of that community. Several items must be accomplished even before the present needs can be adequately met. These are: to provide storage to meet peak demands; enlarge the transmission mains; and provide one or two large capacity wells to prevent low pressure during peak demand hours.

The city of Tumwater, using ground water in the Deschutes Basin can develop adequate water to meet future demands though 2020. However, storage must be provided to meet peak demand with adequate water pressure.

A comparison of projected water supply development and projected water use demonstrates that adequate supplies of both surface and ground water are available within the Basins to meet all anticipated future needs.

BASIN PLANS

"The Olympia Area lies in a broad ground water area with eight subareas economically available for development of good quality water. Six are within or near urban centers. Extensive testing would be required

TABLE 9-11. M & I Water Supply-Capital Improvements
Nisqually-Deschutes Basins

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	22,632	51,100	100,700	157,400
OLYMPIA				
Optimum	—	33.6	66.3	103.6
Capital Improvements	—	12.6	32.7	37.3
Population Served	—	11,600	23,400	40,000
LACEY				
Optimum	[illegible]	7.6	15.4	26.3
Capital Improvements	2.0	4.6	7.8	10.9
Population Served		11,600	23,400	40,000
TUMWATER	—			
Optimum	—	7.6	15.4	26.3
Capital Improvements	2.0	4.6	7.8	10.9
Population Served	10,500	11,000	14,500	21,100
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	6.9	7.2	9.6	13.8
Capital Improvements	5.1	0.3	2.4	4.2
Population Served	—	—	—	—
SELF SUPPLIED INDUSTRY				
Optimum	2.0	3.4	6.7	13.2
Capital Improvements	0.3	1.4	3.3	6.5
Population Served	—	85,300	162,000	285,500
TOTAL				
Capital Improvements	—	29	54	70

NOTE: Figures are rounded.

to learn the true potential of each area, but there appears to be a potential for upwards of 100 mgd from these ground water areas for the future needs of Olympia, Lacey and Tumwater."

Reference:

"Potential Sources of Ground Water, City of Olympia, Water Needs and Sources, July 1968", Arvid Grant & Associates, Construction Engineers, Olympia.

Table 9-11 includes present and future needs through the year 2020 for the major water users in the basins.

The Selected Plan, Table 9-12, for the Nisqually-Deschutes Basin calls for the continued and expanded development of existing ground water sources through the year 2020 to meet all municipal, industrial, and self-supplied industrial water needs. System development, costs, and projected annual revenue are also shown for the basins.

Current indications (Report—"City of Olympia, Needs and Sources, Arvid Grant & Associates, July 1968") are that further accelerations of population projections can be expected to occur beyond that shown in Figure 9-3, Projected Population Growth, largely due to the new four-year college, which will be located immediately northwest of Olympia proper. Unquestionably, a new college will grow at a high rate for its first years of operation. The means to satisfy needs for this basin will be those developments which the city of Olympia has considered in their report.

The "City of Olympia Report" also calls for the development of, in 1970 and again in 1990, a 5 mgd block of water to be used for industrial purposes.

TABLE 9-12 M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Nisqually-Deschutes Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
OLYMPIA												
Present	GW	Develop Local Ground Water McAllister Spgs.	Exist.	3	16	21				35		350
1980	GW	ADD: Capacity to McAllister Springs	1970	16	18	18	1,080			61		1,214
2000	GW	New Well Field Developed		33	33	28	1,980			94		2,710
2020	GW	Additional development & McAllister Springs	1995	56	37	37	2,220			115		4,088
OLYMPIA SELECTED PLAN TOTAL					104	104	$ 5,280					
TUMWATER												
Present	GW	Local Ground Water Development (Present Need)	Exist.	0.3	1.0	1.0				3		35
		Local Ground Water Development 2.0mgd			2.0	2.0	120					
1980	GW	Local Ground Water Development 1.5mgd	1970	2.2	4.6	4.6	276			13		256
2000	GW	Local Ground Water Development 3.5mgd		4.3	7.8	7.8	468			25		502
2020	GW	Local Ground Water Development 4.0mgd		7.1	10.4	10.4	654			41		329
TUMWATER SELECTED PLAN TOTAL					26.3	26.3	$ 1,518					
LACEY												
Present	GW	Local Ground Water Development	Exist.	0.3	1.0	1.0				3		35
		Local Ground Water Development 2.0mgd			2.0	2.0	120					
1980	GW	Local Ground Water Development 1.5mgd	1970	2.2	4.6	4.6	276			13		256
2000	GW	Local Ground Water Development 3.5mgd		4.3	7.8	7.8	468			25		502
2020	GW	Local Ground Water Development 4.0mgd		7.1	10.9	10.9	654			41		829
LACEY SELECTED PLAN TOTAL					26.3	26.3	$ 1,518					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water Development	Exist.	3	1.8	1.8				7		117
		Local Ground Water Development 5.1mgd			5.1	5.1	30					
1980	GW	Local Ground Water Development		2	0	0				21		234
2000		Local Ground Water Development 2.5mgd		3	2.5	2.5	15			31		360
2020	GW	Local Ground Water Development 4.5mgd		6	4.5	4.5	27			51		584
SMALL & RURAL COMMUNITY SYSTEMS SELECTED PLAN TOTAL					14	14	$ 72					
SELF SUPPLIED INDUSTRY												
1965	GW	Local Ground Water Development	Exist.	1.7	2	2						190
1980	GW	Local Ground Water Development	1980	2.6	2	2	150			25		304
2000	GW	Local Ground Water Development	2000	5	2	2	120			21		584
2020	GW	Local Ground Water Development	2020	10	4	4	240			40		1,168
SELF SUPPLIED INDUSTRY ALTERNATIVE PLAN TOTAL					10	10	$ 510					
SELECTED BASIN PLAN TOTAL							$8,888					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs

[c] All figures are rounded.

The Alternative Basin Plan calls for the development of surface water to meet all future needs in the Olympia urban area. This includes the Lacey and Tumwater vicinities.

Three surface water sources which were recommended to the City of Olympia are of adequate quality and quantity as supply sources. All require extensive source development, quality assurance or treatment, and transmission in comparison to ground water sources.

These are: (1) Deschutes River; (2) Nisqually River; and (3) the South Fork of the Skokomish River.

The Deschutes River near Shellrock Ridge was chosen as the most feasible location for a development.

The Alternative Plan is estimated to cost nearly $19 million; this is approximately twice that of the Selected Plan amounting to $ 8 million. Complete cost and income data for the Alternative Plan can be found in Table 9-13.

The storage and distribution costs will be the same for the Selected and Alternative Plans. This cost information is shown in Tables 2-12 and 2-13 the Selected and Alternative Plans.

Surface and ground water supplies can be economically utilized by self-supplied industry and rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

TABLE 9-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Nisqually-Deschutes Basins

					OPTIMUM CAPACITY M G D		1967 THOUSAND DOLLARS: AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treatment	Iron Removal	Pumping Power	Chem.	Total Annual Income
COUNTY WIDE SERVICE (Olympia, Lacey, Tumwater & Vicinity)												
1985	GW	Local Ground Water	Exist.	4	16	21						
	SW	[a]Deschutes River Shellrock Ridge Dam Reservoir (40,000 AF) Gravity Flow	1970		106	108	16,607			38	3	467
1990	SW	Reservoir (40,000 AF) Gravity Flow Local Ground Water		21	8	5	460			32	8	1,725
2000	SW	Reservoir (40,000 AF) Gravity Flow Local Ground Water		42	12	10	680			53	17	3,086
2020	SW	Reservoir (40,000 AF) Gravity Flow Local Ground Water		70	14	14	840			74	28	5,110
COUNTY WIDE SERVICE ALTERNATIVE PLAN TOTAL					156	156	$18,562					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water Development	Exist.	1	1.0	1.0				3		117
1985		Local Ground Water Development			2.0	2.0	120					
1990	GW	Local Ground Water Development		2	1.5	1.5	80			13		234
2000	GW	Local Ground Water Development		3	3.5	3.5	210			25		340
2020	GW	Local Ground Water Development		5	4.0	4.0	240			41		584
SMALL & RURAL COMMUNITY SYSTEMS ALTERNATIVE PLAN TOTAL					12	12	660					
SELF SUPPLIED INDUSTRY (No Feasible Alternative)					10	10	$ 510					
ALTERNATIVE BASIN PLAN TOTAL							$19,712					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

Table 9-11, Summary of Projected Water Needs, shows the level of need to 2020 from all sources.

FINANCE

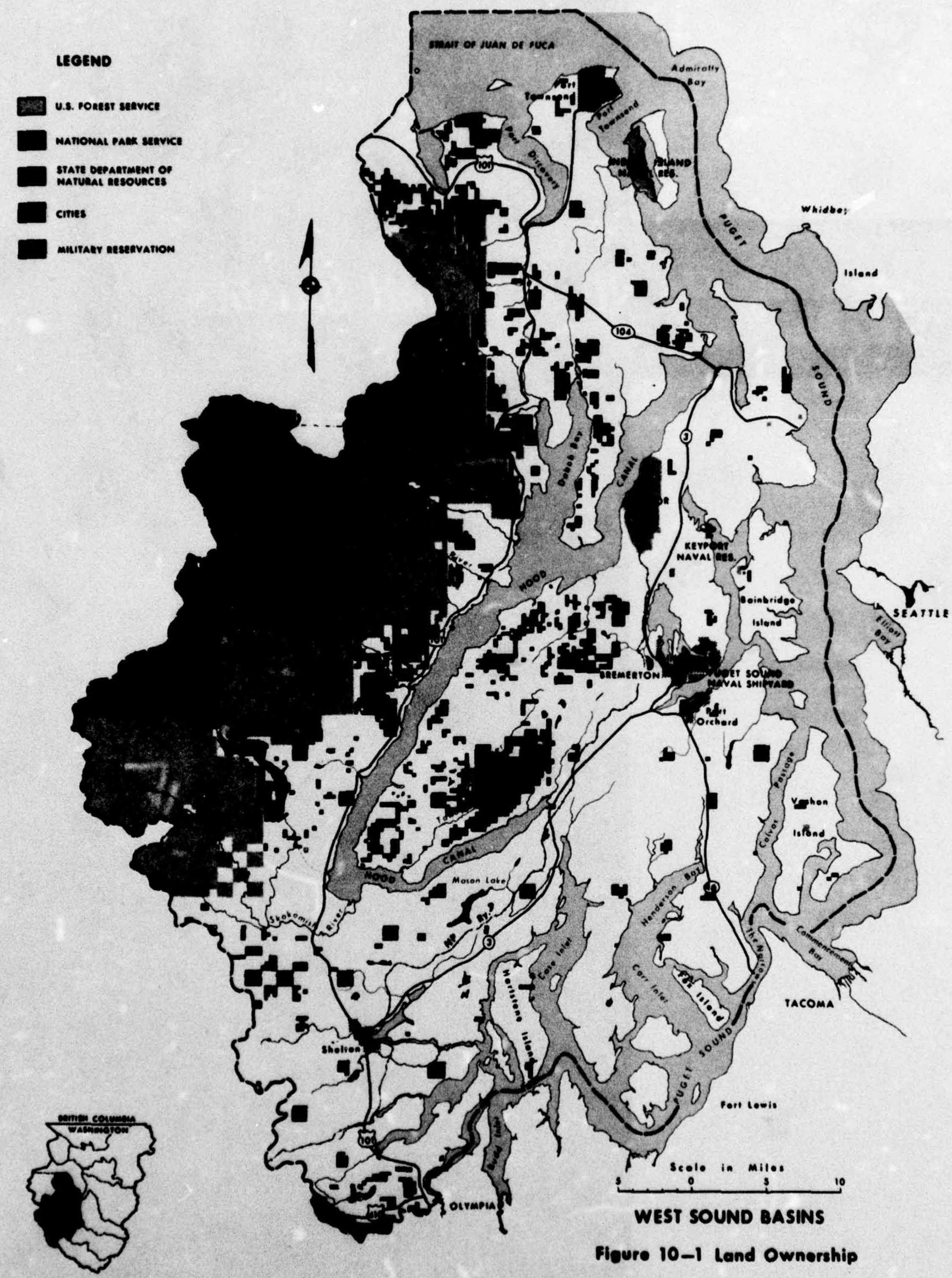
Annual income as taken from Table 2-12 and 2-13 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

	Annual Bond Service Available (x $1,000)		Annual Amortized Cost (x $1,000)	
Year	Selected Plan	Alternate Plan	Selected Plan	Alternate Plan
1965	156	125	79	209
1980	506	484	126	207
2000	995	524	421	458
2020	1,605	1,468	638	611

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that the immediate bond service requirements and those after 1980 will be met by income and construction of water supply developments but will not involve excessive financial burden or rate increases.

West Sound Basins



WEST SOUND BASINS

Figure 10—1 Land Ownership

WEST SOUND BASINS

INTRODUCTION

The West Sound Basins, Figure 10-1, comprise nearly 2,022 square miles of land and water lying between the centerline of the main channel of Puget Sound and the crest of the Olympic Mountains, and is bounded on the north by the Strait of Juan de Fuca and by Budd Inlet on the south.

GEOGRAPHY

The West Sound Basins are divided into two distinct types of terrain: rough, mountainous areas in the Olympic Peninsula west of Hood Canal and the relatively low, flat land of the Kitsap Peninsula east of Hood Canal.

The Olympic Peninsula is comprised largely of forested foothills and mountains, with altitudes varying from sea level to 7,700 feet. Conversely, the Kitsap Peninsula is basically flat to undulating, with hills and ridges separated by valleys and marine embayments. The Green Mountain-Gold Mountain area west of Bremerton is the only mountainous terrain on the peninsula, and comprises a small group of rugged foothills rising as much as 1,761 feet above sea level. The extensive shoreline of the basin is indented with numerous bays, coves, and harbors. Many islands, ranging in size from less than one square mile to several hundred square miles dot the waters of the basin.

The western portion of the basin lying on the Olympic Peninsula is drained by a number of large, swift streams, largest of which are the Skokomish, Hamma Hamma, Duckabush, Dosewallips, Big Quilcene, and Little Quilcene rivers.

The Kitsap Peninsula is drained by 426 separate stream systems, only 12 of which have a drainage area greater than 10 square miles. Most have a drainage area less than one square mile.

CLIMATE

The basin has a characteristically maritime climate, typified by relatively short, cool, dry summers and prolonged, mild, wet winters. Total annual precipitation varies from 220 inches in the mountainous western portion to 25 inches in the northern part. The significantly lesser precipitation in the northern part of the basin is the result of a rain shadow effect caused by the Olympic Mountains. This rain shadow, however, has little effect in the southern part of the basin.

POPULATION

The Basins are estimated to have a population of about 128,000 in 1965. The major population center is Bremerton, with a population of 36,170. An additional 30,000 persons reside in the surrounding metropoliatn area. The other cities and towns have populations of less than 6,000 persons each.

ECONOMY

Bremerton is the center of commerce for the basin. The Naval Shipyard at Bremerton (photo 10-1) is the second largest industrial employer in the Puget Sound area. Other extensive Naval installations in the West Sound Basins include the Naval Torpedo Station at Keyport and the Naval Ammunition Depot and the Pacific Polaris Missile Facility at Bangor.

Forest product industries range from Crown Zellerbach's pulp and paper mill at Port Townsend to Christmas tree farms near Shelton. The focal point of tne basin logging industry is Shelton, where a complex of plants controlled by the Simpson Timber Company are located.

Agricultural activities are the third largest contributor to basin economy. Dairy farming and general livestock raising, with some specialty crops, are the primary agricultural pursuits. Numerous small dairy, poultry, and berry farms are scattered about the uplands and creek valleys, and an important growing industry has developed on Bainbridge Island.

The West Sound Basins are noted for its oyster industry. Both Olympia and Pacific oysters are cultivated and harvested on "farms" in tidewater inlets that lace the basin. Totten Inlet is the center of such production, though other commercial oyster farms are located in Oakland Bay, around Hartstene Island, at the head of Case Inlet, and on Hood Canal.

Tourism and outdoor recreation are also assuming an important role in the basin economy. The construction of vacation homes, boating facili-

PHOTO 10-1. Bremerton is the major metropolitan center in the basin.

ties, and the development of new resorts and tourist accommodations are adding considerably to economic stability and growth in the basin.

LAND USE

Forestlands make up about 90 percent of the total acreage in the basin. Most of the urban buildup is confined along the shoreline and bays, leaving the area inland relatively undeveloped. Table 10-1 lists a breakdown of land use in the basin.

TABLE 10-1. General land use.

Use	Acres
Forestland	1,124,000
Cropland	46,000
Rangeland	5,000
Other land (high, barren)	64,000
Urban buildup	42,000
Inland water	13,000
Total land and inland water	1,294,000

Source: Appendix III, Hydrology.

PRESENT STATUS

Municipal and industrial consumers in the West Sound Basins are at present adequately supplied with water from both publically and privately owned systems. The Bremerton municipal system, largest in the Basin, is presently capable of supplying 23 mgd to meet peak transmission rates of 16 mgd.

WATER USE

More than 121,900 persons and numerous industries in the West Sound Basins presently use an average of 49.2 million gallons of water per day; industrial users account for more than 69 percent of this total. Table 10-2 lists the major water systems in the basin and breaks down the municipal, industrial, and rural-individual water use in the various basin areas.

Municipal

About 103,750 municipal consumers in the Basin use an average of 14.4 mgd, 29 percent of total Basin water consumption. The basin-wide per capita use is 139 gpd. More than 42,000 municipal consumers in the city of Bremerton, largest water user in the Basin, use an average of 6.5 mgd, a per capita use of 155 gpd. Approximately 7,500 persons in Port Townsend each use an average of 200 gpd, a total use of 1.5 mgd. Nearly 38,000 residents of rural communities such as Shelton, Poulsbo, Winslow, and Gig Harbor use an average of 4.4 mgd, a per capita use of 115 gpd.

Industrial

Industrial water use in the Basin averages more than 33 mgd, 69.3 percent of the total water used in the basin. The pulp and paper industry, largest single industrial water user in the Basin, uses an average of 29.7 mgd, approximately 89 percent of the water used for industrial purposes and about 60 percent of all water used in the Basin. The Puget Sound Naval Shipyard at Bremerton, second largest industrial water user in the Basin, uses 2.9 mgd, about 6 percent of total industrial use. the remaining 1.0 mgd is consumed by various food plants and the lumber and wood and stone, clay, and glass industries.

Rural-Individual

More than 18,150 rural-individual consumers use an average of about 1.0 mgd, a per capita use of less than 60 gpd.

TABLE 10-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd)			Ground water usage (mgd)		
		Average daily	Maximum monthly	Maximum daily	Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Bremerton	42,000	5.35	7.80	10.60	1.15	3.20	5.40
Olympic Gravity Water System (Pt Townsend)	7,500	1.5	3.00	4.50	—	—	—
Shelton	5,800	—	—	—	1.00	2.00	3.00
Port Orchard	5,000	—	—	—	0.40	0.80	1.50
Poulsbo Water System	1,700	—	—	—	0.20	0.55	0.90
Winslow Water Supply	1,400	—	—	—	0.18	0.35	0.53
Gig Harbor	1,280	—	—	—	0.10	0.10	0.11
Water District No. 19	1,100	—	—	—	0.07	0.14	0.22
Other rural community systems	37,970	0.42	0.80	1.14	4.00	7.42	10.83
Subtotal	103,750[b]	7.30	11.60	16.20	7.10	14.60	22.50
RURAL-INDIVIDUAL USE	18,150	0.10[a]	0.14	0.20	0.90[a]	1.30	1.80
INDUSTRIAL USE							
Municipally supplied:							
Bremerton							
Chemicals, metals, oils		2.40	2.60	2.75	0.50	0.60	0.80
Port Townsend							
Food and kindred		0.01	0.01	0.01	—	—	—
Paper and allied		13.80	15.20	16.60	—	—	—
Shelton							
Lumber and wood		—	—	—	0.40	0.60	0.80
Paper and allied		—	—	—	0.05	0.05	0.05
Self-supplied:							
Lumber and wood		0.78	9.66	18.43	—	—	—
Paper and allied		13.60	15.00	16.30	2.25	2.50	2.70
Food and kindred		—	—	—	0.02	0.02	0.03
Stone, clay, glass		0.02	0.02	0.02	—	—	—
Subtotal		30.60	42.50	54.10	3.22	3.80	4.40
Total	121,900	38.00	54.20	70.60	11.22	18.50	27.10

[a]Based on 55 gpcd and 90 percent of rural individual population served by ground water.

[b] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

WATER SUPPLIES

Water for the basin is supplied by about 273 separate systems ranging in size from small privately owned systems serving only a few people to the large Bremerton public system which served a population of about 42,000 in 1965.

Water for municipal, industrial, and domestic purposes is supplied from both surface and ground sources, though surface sources supply 77 percent (37.9 mgd) of the total water demand in the basin.

Municipal

The city of Bremerton, with the largest water supply system in the West Sound Basins utilizes both surface and ground water sources for its supply.

Ground water is drawn from seven wells; Union River, Gorst Creek, Anderson Creek, and several other small streams provide surface water. Cascade Dam above McKenna Falls diverts water from the Union River through pipelines to a settling basin before distribution. At the present time (based on 1965 statistics), the system, with a firm supply capacity of about 23 mgd and a transmission capacity of 16 mgd, supplies Bremerton average water requirements of 6.5 mgd. Acess to the Bremerton watershed is carefully controlled, and surface water supplied from this watershed requires treatment only with chlorine and ammonia for disinfection and control of tastes and odors.

Port Orchard obtains its water from four artesian wells, and supplies an average of 0.4 mgd of untreated water to about 5,000 persons.

Port Townsend obtains its water from the Big Quilcene River. This system supplies an average of 1.5 mgd to about 7,500 persons.

Most of the remaining water systems in the basin rely on ground water to supply about 4.5 mgd to nearly 38,000 persons in the rural communities.

Industrial

Industries located at Bremerton, Port Townsend, and Shelton are supplied by the respective municipal water systems. Bremerton supplies industry with 2.90 mgd. Several industries in the basin have their own water supplies.

Pulp and paper mills, located in Port Townsend, draw an average of 30 mgd from the Port Townsend water system and self-supplied sources.

Rural-Individual

An estimated 18,150 persons are served by individual wells or springs.

WATER RIGHTS

The West Sound Basins have a total of 2,145 recorded water rights; of these, 1,787 are surface and 358 are ground (1966-1967).

Prime surface water rights have been issued for a total of 2,008 mgd. On a quantitative basis, the most important use is power generation with a total rate of diversion of 1,733 mgd. Other categories and rates of diversion are municipal, 41 mgd; commercial and industrial, 60 mgd; individual and community domestic, 73 mgd; and fish propagation, 124 mgd. Supplemental rights totaling only 4 mgd have been granted for the above categories. Storage is authorized for 440,800 acre-feet.

As of April 30, 1967, applications for water rights had been received for 950 mgd by the Department of Water Resources. Applications are pending for 10,600 acre-feet for reservoir storage in the basin.

Due to critical low-flows, many streams in the basin are either closed to consumptive diversion or have low-flow restrictions on them.

Ground water prime right diversion amounts to 86 mgd, with supplemental rights totaling 0.8 mgd. Municipal and industrial and community domestic require the largest amounts of water (43 mgd) due to the many small community systems. Industrial water appropriations total approximately 33 mgd. The remaining rights fall mainly in appropriations for irrigation.

Average well production in the basin is 0.2 mgd; however, many wells produce in excess of 1.4 mgd – one reportedly as high as 6.5 mgd. Table 10-3 shows water rights in the basin.

TABLE 10-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	44.1	75.7	59.3
Ground water	15.1	40.7	23.3
Total[a]	59.2	116.4	82.6

[a]About 1,809 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

Both surface and ground waters are plentiful in the West Sound Basins and are, in general, of excellent quality, though ground water sources are limited in some areas. In addition, the larger surface water sources are remote from the urban areas. However, sufficient supplies are available on the more urban

Kitsap Peninsula to supply present and anticipated requirements.

SURFACE WATER

Surface water, which supplies 77 percent of all water used in the basin, is plentiful and of excellent quality, but the major concentrations are on the Olympic Peninsula where population is sparse and major development in the future is unlikely. The Bremerton watershed is capable of providing sufficient water to satisfy present needs of the major urban area.

Quantity Available

Streams. The West Sound Basins are drained by a number of rivers and creeks that empty into the waters of Puget Sound. The Big Quilcene, Dosewallips, Duckabush, Hamma Hamma, Skokomish, and Tahuya Rivers are of major importance to the water resources of the area. The mean annual runoff of the Dosewallips River adjusted to the period 1931 through 1960 is 475 cfs. Adjusted to the same period, the mean annual runoff of the Duckabush River, measured near Brinnon, is 407 cfs. The mean annual runoff of the Hamma Hamma River near Eldon averaged 320.3 cfs for the same period. Streams heading in the Olympics have two peak flow periods: one during high winter precipitation, and the other during the spring rains and snowmelt period. Farther to the south, where the effect of the rain shadow is less pronounced, the winter peak becomes dominant, and the two seasonal peaks tend to merge into one long period of high flows.

In general, minimum monthly flows for streams in the southern portion of the basin occur during the months of August and September; in the northern areas, miminum flows extend into October.

A low flow frequency analysis has been made by the USGS for 22 discharge stations in the West Sound Basins. The 7-day and 30-day low flows that can be expected to occur at 7 of these stations for recurrence intervals of 5, 10, and 20 years are shown in Table 10-4.

TABLE 10-4. Low-flow frequency

Discharge station	Recurrence interval (years)	7-day low-flow (cfs)	30-day low-flow (cfs)
Little Quilcene River near Quilcene	5	8.40	9.60
	10	7.30	8.40
	20	6.60	7.50
Dosewallips River near Brinnon	5	114.00	132.00
	10	106.00	123.00
	20	100.00	118.00
Duckabush River near Brinnon	5	64.00	79.00
	10	58.0	70.00
	20	53.00	64.00
Skokomish River near Potlatch	5	160.00	176.00
	10	151.00	168.00
	20	144.00	160.00
Union River near Belfair	5	15.00	16.00
	10	14.00	15.00
	20	13.30	14.00
Gold Creek near Bremerton	5	0.40	0.45
	10	0.36	0.40
	20	0.32	0.36
Goldsborough Creek near Shelton	5	17.30	19.00
	10	16.00	17.80
	20	15.20	16.80

Dams and Impoundments. Flows of the North Fork of the Skokomish River have been regulated by Lake Cushman since 1925. This reservoir has over 453,000 acre-feet storage and 350,000 acre-feet of active storage. The power diversions here preclude any appreciable discharge in the North Fork of the Skokomish River below Cushman No. 2 Dam. This is the only major storage reservoir in the West Sound Basins, leaving all other streams essentially in an unregulated state, except for the Union River at the small Casad Dam.

Quality

The West Sound Basins contain a number of rivers and creeks on which water quality measurements have been made. Table 10-5 summarizes water quality data gathered since early 1959 from seven monitoring stations in the basin.

Physical. Stream temperatures in the basin are significantly low. A maximum summer stream temperature of 17.0°C (62.6°F) was recorded on Goldsborough Creek. Records from other stream gaging stations indicate slightly lower maximums. A maximum temperature of 15.6°C (60.1°F) was recorded for the Big Quilcene River near Quilcene.

Smaller streams in the basin particularly on the Kitsap Peninsula, are appreciably colored at times. The color is attributed largely to organic materials from swamps and poorly drained marshy areas. Maxi-

TABLE 10-5. Surface water quality

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (μmho)	Orthophosphate (PO_4) (mg/l)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
		mg/l												mg/l									mg/l		mg/l		
BIG QUILCENE RIVER NEAR QUILCENE — JULY 1960 THROUGH AUGUST 1966																											
Maximum	---	94	18.0	2.9	7.8	0.4	52	0	3.4	21.0	0.2	1.0	158	0.32	---	12.0	0.49	0.06	7.8	15	5	15.6	13.5	117	57	14	430
Mean	---	62	12.8	2.0	3.6	0.2	45	0	2.4	6.8	0.1	0.3	99	0.03	---	9.5	0.09	0.02	---	---	---	8.9	11.4	102	40	3	42
Minimum	---	43	9.0	1.1	1.6	0.0	36	0	1.6	2.0	0.0	0.0	72	0.00	---	7.2	0.00	0.00	6.8	0	0	3.6	9.8	93	30	0	0
Number	---	29	29	29	29	29	29	16	29	29	29	29	29	27	---	29	27	12	29	29	10	28	27	26	29	29	29
DOSEWALLIPS RIVER AT BRINNON — JULY 1959 THROUGH AUGUST 1966																											
Maximum	---	72	18.0	2.0	3.3	0.6	56	0	8.4	1.5	0.2	0.4	114	0.10	---	9.4	1.30	0.05	7.9	10	80	15.5	13.6	113	52	6	230
Mean	---	53	13.5	1.1	1.7	0.2	43	0	6.2	0.8	0.1	0.2	86	0.02	---	6.7	0.14	0.02	---	---	---	8.8	11.6	103	38	3	29
Minimum	---	38	8.5	0.2	0.9	0.0	27	0	4.2	0.2	0.0	0.0	57	0.00	---	4.3	0.00	0.00	6.9	0	0	3.9	10.0	94	24	2	0
Number	---	29	29	29	29	29	29	16	29	29	29	29	29	27	---	29	27	12	29	29	10	28	26	25	29	29	29
DUCKABUSH RIVER AT U.S. 101 BRIDGE NEAR BRINNON — JULY 1959 THROUGH AUGUST 1966																											
Maximum	1,140	133	47.0	113.0	29.0	1.0	50	0	11.0	1700	0.3	0.4	5550	0.07	---	7.6	0.28	0.17	7.9	10	25	15.1	13.9	130	276	240	430
Mean	---	47	13.0	10.5	3.4	0.2	35	0	4.5	140.1	0.1	0.1	538	0.01	---	6.0	0.06	0.04	---	---	---	8.5	11.8	103	56	28	84
Minimum	64	33	6.5	0.5	0.9	0.0	24	0	2.4	0.2	0.0	0.0	46	0.00	---	3.7	0.01	0.00	7.1	0	0	4.1	8.0	75	20	0	0
Number	22	21	26	26	21	21	27	12	21	27	22	21	27	19	---	22	19	10	27	22	9	26	25	24	26	26	27
HAMMA HAMMA RIVER AT ELDON — NOVEMBER 1961 THROUGH AUGUST 1966																											
Maximum	450	77	23.0	48.0	14.0	0.7	38	0	5.4	685	0.1	0.3	2400	0.03	---	9.1	0.36	0.05	7.6	5	5	13.0	13.9	119	257	228	430
Mean	---	42	9.4	5.2	2.5	0.3	32	0	2.8	59.7	0.0	0.2	277	0.01	---	7.4	0.06	0.01	---	---	---	8.9	12.0	107	46	20	47
Minimum	119	32	5.0	0.9	1.0	0.0	22	0	1.6	0.5	0.0	0.0	41	0.01	---	5.4	0.00	0.00	6.8	0	0	5.5	11.0	100	17	0	0
Number	4	11	12	12	11	11	13	13	11	12	11	11	13	9	---	11	9	9	13	11	10	12	13	12	12	12	13
SKOKOMISH RIVER NEAR POTLATCH — AUGUST 1960 THROUGH AUGUST 1966																											
Maximum	6,840	52	9.5	2.5	2.7	0.5	43	0	2.2	2.5	0.1	0.7	77	0.06	---	14.0	2.90	0.04	7.8	15	70	13.5	15.0	128	33	0	230
Mean	---	45	8.0	1.7	2.0	0.2	35	0	1.1	1.4	0.1	0.2	63	0.03	---	11.7	0.25	0.01	---	---	---	8.7	11.0	97	27	0	56
Minimum	190	31	5.0	0.9	1.4	0.0	24	0	0.0	1.0	0.0	0.0	43	0.00	---	8.3	0.01	0.00	6.7	0	0	5.1	9.6	88	18	0	0
Number	22	26	26	26	26	26	26	12	26	26	26	26	26	24	---	26	24	12	26	26	10	24	24	23	26	26	25
CHICO CREEK NEAR BREMERTON — NOVEMBER 1964 THROUGH SEPTEMBER 1966																											
Maximum	---	64	9.5	3.5	3.4	0.8	50	0	3.6	3.0	0.1	2.7	91	0.08	---	15.0	0.20	0.01	7.7	20	10	17.3	10.6	106	38	2	2,400
Mean	---	51	7.5	2.7	3.0	0.4	37	0	2.8	1.9	0.1	1.0	73	0.04	---	11.3	0.10	0.01	---	---	---	13.7	10.2	102	30	0	1,743
Minimum	---	36	5.2	1.7	2.0	0.0	24	0	0.4	0.5	0.0	0.0	49	0.01	---	8.0	0.05	0.01	6.9	0	0	11.8	9.9	97	20	0	430
Number	---	18	18	18	18	18	18	18	18	18	18	18	18	8	---	18	8	1	18	18	8	3	3	3	18	18	3
GOLDSBOROUGH CREEK NEAR SHELTON — NOVEMBER 1964 THROUGH SEPTEMBER 1966																											
Maximum	---	178	32.0	14.0	4.7	0.7	150	0	11.0	6.2	0.2	1.1	255	0.13	---	19.0	0.66	0.02	8.2	90	20	17.0	12.5	110	136	8	4,600
Mean	---	99	17.0	6.9	3.6	0.4	81	0	5.9	3.2	0.1	0.6	149	0.05	---	14.9	0.33	0.01	---	---	---	10.4	10.5	96	71	4	878
Minimum	---	40	4.8	1.8	2.0	0.1	21	0	2.4	1.5	0.0	0.3	49	0.00	---	8.2	0.17	0.00	6.8	20	0	4.5	8.3	84	20	0	36
Number	---	24	24	24	24	24	24	24	24	24	24	24	24	12	---	24	12	3	24	21	12	23	23	22	24	24	23

mum color values of 90 and 20 units have been recorded on Goldsborough and Chico Creeks, respectively.

Suspended sediment concentrations for most streams in the West Sound Basins are relatively low. Sediment data collected from the Skokomish River near Potlatch during 1965 and 1966 indicate an average yearly transported sediment load of about 100,000 tons. However, it transports as much as 40,000 tons per day when the mean daily discharge exceeds 10,000 cfs. Sediment data for the Dosewallips, Duckabush, and Hamma Hamma Rivers indicate a much lower average annual transported sediment load of about 4,000 tons.

Turbidity is generally low throughout the Basin. Usually, turbidity for the principal water courses is less than 10 JTU, although maximums of 80 and 70 JTU have been recorded for the Dosewallips and Skokomish Rivers, respectively.

Chemical. For the most part, waters in the basin are soft, with average hardness values recorded at the seven stations ranging from 0 to 63.2 mg/l. Dissolved solids concentrations are small, ranging from 31.0 mg/l to 175 mg/l. Slightly greater concentrations of dissolved solids are found in Goldsborough Creek, with a recorded maximum of 170 mg/l. Iron concentrations are low. Averages range from 0.06 to 0.33 mg/l, and a maximum of 2.90 mg/l was recorded per the Skokomish River near Potlatch.

All the streams within the basin have high dissolved oxygen concentrations with averages ranging from 10.2 to 12.0 mg/l.

Bacteriological. Samples taken from the Dosewallips and Duckabush Rivers near Brinnon, the Big Quilcene River near Quilcene, the Hamma Hamma River at Eldon, and the Skokomish River near Potlatch indicate very low median coliform concentrations. Maximum coliform concentrations at these stations are also relatively low, the highest recorded concentration being 430 MPN. Higher coliform concentrations are observed on Goldsborough Creek at Shelton and Chico Creek near Bremerton. Maximum MPN's of 4,600 and 2,400 coliforms/100 ml were recorded on Goldsborough Creek and Chico

Creek, respectively. Although data is not available for the Sound waters at Bremerton, it is believed that the Puget Sound Naval Shipyard contributes enough raw sanitary waste to the waters to adversely affect their bacteriological quality.

GROUND WATER

Quantity Available

Ground water supplies are plentiful in the West Sound Basins, but vary greatly in quantity available between areas of differing geological structure. Water yields on the Olympic Peninsula range from a maximum recorded 4,160 gpm from a well near Shelton to less than 10 gpm for wells in the Olympic National Park. Well yields as high as 720 gpm are reported in the northern lowlands of the Olympic Peninsula, and pumping rates of 200 gpm or more are common. Water yields in the southern lowlands are considerably greater, some wells approaching 1,500 gpm. Wells in the northern lowlands of the Kitsap Peninsula, however, are likely to have very low yields.

Practically all recharge to the basin aquifers is from precipitation, with the southern lowlands receiving about 120,000 acre-feet of recharge per year. The natural discharge of ground water is mostly into the larger streams or directly into Puget Sound through springs.

Quality

Limited quality data are available for ground waters of the West Sound Basins. The concentration of dissolved solids normally ranges from 100 to 200 mg/1, and hardness ranges between 50 and 100 mg/1. In some of the shoreline areas, where aquifers may contain traces of seawater, concentrations of dissolved solids may exceed 200 mg/1. Nutrient concentrations are generally high with phosphate concentrations averaging about 0.5 to 0.8 mg/l and nitrates averaging 1 to 2 mg/1. Higher values of these parameters have been recorded, as shown in Table 10-6. Although most wells exhibit traces of iron, it is seldom found in excess of 0.3 mg/1.

PRESENT AND FUTURE NEEDS

Future growth and development of the West Sound Basins will require an adequate water supply and orderly planning and development of water distribution facilities to serve domestic, industrial, commercial, and firefighting needs. With about 90 percent of the basin presently undeveloped, several factors indicate that a period of rapid growth is at hand. Principally, these are: (1) desirability of the area for residential development, (2) extensive waterfront areas, (3) the impact of the Tacoma Narrows, Fox Island, and Hood Canal Bridges, (4) development of the Tacoma Industrial Airport, and (5) expansion in paper and allied industries and food processing.

Except for Bremerton, which has a dam and reservoir on the Union River, the basin has depended mainly on ground water from wells, springs, and artesian wells. The Bremerton Water Department also draws water from wells, and the city has further surface water availability on the Tahuya, and Hamma Hamma Rivers and Jefferson Creek (existing 50 cfs right). Bremerton's future needs include the need to acquire and control watershed land to ensure high-quality water.

Presently, Port Orchard obtains water from artesian wells. Total flow is 2.6 mgd (1,845 gpm), with total available of 3.3 mgd by pumping. This supply is adequate to 1980. All demands are furnished from resources developed in the 1960s. Sustained yields of 5 mgd are estimated to be possible from the entire productive artesian zone.

Water for Poulsbo presently comes from three springs, with a firm supply of 0.8 mgd. The town can acquire no further water rights near its springs, but extensive and adequate ground water recharge and potentially productive areas are available just east of Poulsbo in the Lincoln area and in the Bangor-Silverdale area.

Bainbridge Island lacks productive quantities of water. To date, aquifers tapped produce only small quantities. Winslow, unable to develop large-capacity wells, must rely on many low-producing wells and augment peak demands with water from a stream over which the town has no control. The difficulty of finding even small quantities of ground water in the Fort Ward area is reflected in the extensively large reservoirs used to store water from surface sources. An adequate supply of good-quality water after 1980

TABLE 10-6. Ground water quality.

Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2) (mg/l)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3) (mg/l)	Orthophosphate (PO_4)	Dissolved solids	Hardness ($CaCO_3$)	Specific conductance (μmho)[c]	pH
						Cations (mg/l)									
State of Washington	30/3W-25C1	12/16/59	52	17	1.70[d]	7.3	0.9	300.0	0.8	0.2	0.22	778	22	1420	8.0
Kenneth Lake	22/1-12D2	10/4/60	50	38	0.09	12.0	1.5	19.0	2.6	0.1	0.27	120	36	151	8.3
A. Steiner	22/1-12R2	10/4/60	58	18	0.03	15.0	1.8	11.0	0.9	4.9	0.04	100	45	151	6.3
Sunnyslope Water Development Co.	23/1-7D1	3/2/61	40	25	0.01	9.0	4.5	3.7	0.5	0.1	0.11	68	41	99	8.0
J. P. Noble	23/2-2L3	10/4/60	54	33	0.05	15.0	8.8	7.8	2.1	0.1	0.43	120	74	176	8.1
Eugene Logan	24/1W-35P1	10/4/60	49	21	1.30[d]	7.0	2.7	2.8	0.4	4.0	0.02	60	29	74	7.0
City of Port Orchard (wells)	24/1-25M1	3/3/61	49	35	0.04	18.0	3.6	5.5	1.4	0.1	0.34	105	60	142	8.4
City of Bremerton (well 5)	24/1-33K5	12/16/59	54	31	0.01	15.0	2.6	6.9	1.7	0.0	0.38	101	48	129	8.3
W. L. Cheney	24/2-33H1	2/28/61	51	38	0.06	15.0	2.2	17.0	2.0	0.1	0.91	119	46	168	8.5
B. P. Bitle	25/1-23K	2/28/61	47	20	3.30[d]	10.0	6.1	4.7	0.4	1.4	0.08	81	50	121	6.8
Baxter-Wycoff Co. (well 3)	25/2-35H3	10/5/60	53	26	0.041[d]	20.0	12.0	18.0	2.0	0.1	0.19	164	100	264	8.2
H. I. Foss	25/2-35M2	2/27/61	50	28	2.30[d]	11.0	12.0	7.5	0.6	5.3	0.11	114	77	184	7.4
U.S. Government (U.S. Army)	26/1-10L	3/24/59	40	27	0.01	9.0	6.6	3.5	1.1	5.1	--	85	50	118	7.4
E. Bowman	26/1-13J1	2/28/61	48	24	0.15	8.0	4.0	4.0	0.4	10.0	0.11	70	36	101	7.5
U.S. Government (U.S. Navy well 1)	26/1-36P1	10/5/60	53	33	0.24	28.0	5.3	20.0	1.9	3.4	2.10	182	92	274	7.6
State of Washington	27/2-25N1	2/27/61	52	39	0.15	14.0	9.2	16.0	3.2	0.1	0.82	149	73	213	8.1
E. D. Buyer	28/2-35M2	2/27/61	49	31	0.04	7.6	11.0	7.6	2.5	0.9	0.26	128	82	200	7.9
Simpson Plywood Co.	20/3W-20E	5/24/60	58	16	0.00	3.5	0.0	30.0	0.1	0.0	0.81	102	8	147	9.1
Port of Shelton	20/3W-20H	5/24/60	49	17	0.03	6.0	1.6	2.1	0.0	0.0	0.04	48	22	54	6.7

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180 °C (356 °F).

[c] Micromhos at 25 °C (77 °F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

will depend on sources in other areas. The most suitable approach would be to develop ground sources in the vicinity of Brownsville (directly west of the center of Bainbridge Island) or, alternatively, to obtain water from Bremerton.

Supply requirements for the northern portion of the Kitsap Peninsula, north of Poulsbo, are presently served by numerous water systems along the shoreline. Kingston is the only community with adequate ground water supplies. Other community systems must rely on surface water from uncontrolled watersheds for primary or standby supply. Because no evidence has been found of productive aquifers, and excessive amounts of iron and salt water infiltration have resulted from pumping, facilities to transport water from outside the area are needed.

Western Kitsap Peninsula, extending south from Bangor on Hood Canal to the southern limit of the basin in the Henderson Bay-Carr Inlet area, has been served by shallow ground water supplies and small surface sources. The extent to which ground water supplies can be developed from deeper, more productive aquifers can be determined only by extensive geophysical prospecting.

The Gig Harbor Peninsula lies in the southeastern part of the basin near the Tacoma urban complex. Demand for industrial land, which is not expected to be extensive, will likely be in the town of Gig Harbor and in the area adjacent to the Tacoma Industrial Airport. Except for shoreline areas, less than 10 percent of the peninsula is developed. Population growth has been slow, with summer

homes predominating. However, the growth potential of the area appears to exceed the capability of ground water supplies by 1985. After that, a pipeline across the Narrows Bridge could supply 8 mgd from Tacoma, and development of a surface water supply in Huge Creek could furnish 10 mgd.

Development of regional surface supplies for the entire Kitsap Peninsula is likely limited to Gold Creek (a tributary of the Tahuya River), Huge Creek, and connection to Tacoma Water Department supplies. Gold Creek, about 8 miles west of Bremerton, is well situated to supply most of the section along Hood Canal. Lilliwaup and Lost Creeks could not be used in lieu of Gold Creek if they are to serve as a primary source of transport water to other areas of the peninsula.

Rural-individual and rural community systems in the sparsely settled southern and western areas of the Kitsap Peninsula are apparently in an extensive and productive ground water zone sufficient for present and projected future needs.

The West Sound communities of Shelton and Port Townsend serve municipal and industrial systems adequately in areas of high precipitation and stream flow. The only major effort needed will be to develop facilities to handle increased demand.

PROJECTED POPULATION GROWTH

Figure 10-2 shows projected population growth in the West Sound Basins from 1965 through the year 2020. The 1965 population (121,900) will increase about 43 percent to 175,000 by 1980, about 125 percent to 274,100 by the year 2000, and about 254 percent to 432,700 by 2020. Most of the increase is expected in and around the urban Bremerton-Port Orchard area, on the Gig Harbor Peninsula, on Bainbridge Island, and in and around Port Townsend.

PROJECTED INDUSTRIAL GROWTH

Production growth of the major water-using industries in the basin is projected to increase by 260 percent between 1965 and 2020 in terms of value added. As shown in figure 10-3, the paper and allied industries and food processing industries will predominate by the year 2020. These industries will then account for nearly all the total value added by major water-using industries.

Lumber and wood production is projected to decrease slightly through 2020. Timber usage will shift to the manufacture of pulp and paper. By 2020,

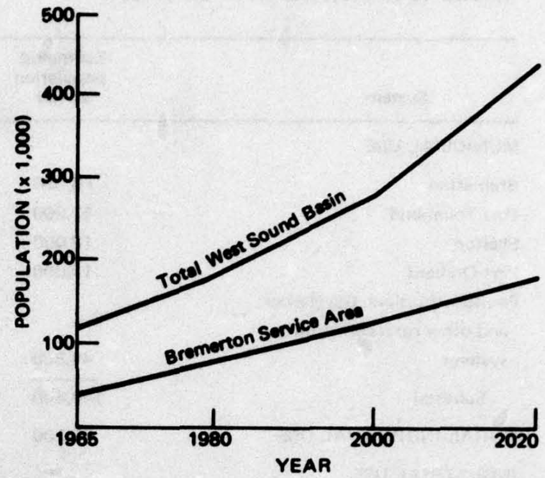


FIGURE 10-2. Projected population growth.

the pulp and paper industry will account for more than 55 percent of all value added by major water-using industries.

PROJECTED WATER REQUIREMENTS

Total water requirements in the basin are expected to reach 182 mgd by the year 2020. This is an increase of more than 370 percent over present requirements. Surface water sources see expected to supply 70 percent of the projected water needs. Tables 10-7, 10-8, and 10-9 itemize projected water use in 1980, 2000 and 2020, respectively. Table 10-10 summarizes water use from the present through 2020.

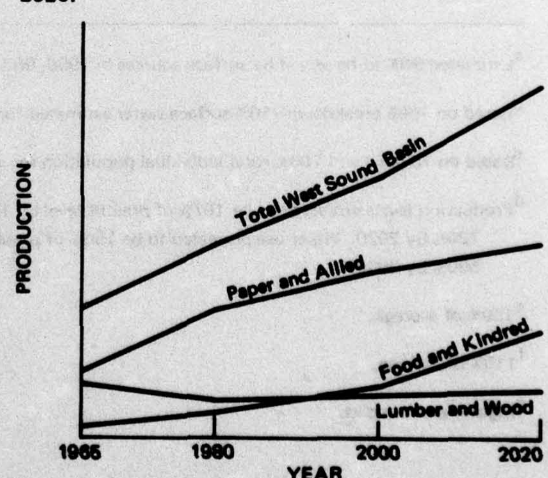


FIGURE 10-3. Relative production growth for major water-using industries.

TABLE 10-7. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Bremerton	70,000	12.00[a]	16.80	1.30	1.80
Port Townsend	12,000	2.30	3.20	—	—
Shelton	12,000	—	—	2.30	3.20
Port Orchard	10,000	—	—	1.90	2.70
Poulsbo, Winslow, Gig Harbor, and other rural community systems	44,800	0.80[b]	1.10	7.70	10.80
Subtotal	148,800	15.10	21.10	13.20	18.50
RURAL-INDIVIDUAL USE	26,200	—	—	1.80[c]	2.60
INDUSTRIAL USE					
Bremerton					
Naval Shipyard	—	3.50	3.80	0.50	0.60
Port Townsend					
Food and kindred[d]	—	0.02	0.03[e]	—	—
Paper and allied	—	27.00	30.00[f]	—	—
Shelton					
Lumber and wood	—	—	—	0.35	0.38[f]
Paper and allied	—	—	—	0.10	0.11[f]
Self-supplied:					
Paper and allied	—	27.00	30.00[f]	3.50	3.80
Lumber and wood	—	0.70	0.80[f]	—	—
Food and kindred	—	—	—	0.03	0.04
Stone, clay, glass	—	0.07	0.07	—	—
Subtotal	—	58.30	64.70	4.50	4.90
Total[g]	175,000	73.40	85.80	19.50	26.00

[a]Estimated 90% to be served by surface sources in 1980, 95% in 2000, and 2020.

[b]Based on 1965 breakdown—10% surface water estimated for 1980-2020.

[c]Based on 70 gpcd and 100% rural individual population served by ground water by 1980.

[d]Production levels projected to be 167% of present level by 1980, 335% by 2000, and 720% by 2020. Water use projected to be 150% of present by 1980, 300% by 2000, 550% by 2020.

[e]150% of average.

[f]110% of average.

[g]Figures are rounded.

TABLE 10-8. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Bremerton	116,700	22.00[a]	31.00	2.40	3.40
Port Townsend	25,000	5.30	7.40	—	—
Shelton	25,000	—	—	5.30	7.40
Port Orchard	15,000	—	—	3.20	4.50
Poulsbo, Winslow, Gig Harbor, and other rural community systems	65,000	1.50[b]	2.10	12.00	16.80
Subtotal	246,700	28.80	40.50	22.90	32.10
RURAL-INDIVIDUAL USE	27,400	—	—	2.50[c]	3.50
INDUSTRIAL USE					
Bremerton					
Naval Shipyard	—	5.00	5.50	1.00	1.20
Port Townsend					
Food and kindred[d]	—	0.03	0.04[e]	—	—
Paper and allied	—	36.00	40.00[f]	—	—
Shelton					
Lumber and wood	—	—	—	0.35	0.38[f]
Paper and allied	—	—	—	0.20	0.22[f]
Self-supplied:					
Paper and allied	—	36.00	40.00[f]	5.00	5.50[f]
Lumber and wood	—	0.70	0.80[f]	—	—
Food and kindred	—	—	—	0.08	0.09
Stone, clay, glass	—	0.08	0.08	—	—
Subtotal	—	77.80	86.40	6.60	7.40
Total[g]	274,100	106.60	126.90	32.00	43.00

[a]Estimated 90% to be served by surface sources in 1980, 95% in 2000 and 2020.

[b]Based on 1965 breakdown—10% surface water estimated for 1980-2020.

[c]Based on 90 gpcd and 100% rural individual population served by ground water by 1980.

[d]Production levels projected to be 167% of present level by 1980, 335% by 2000, and 720% by 2020.
Water use projected to be 150% of present by 1980, 300% by 2000, 650% by 2020.

[e]150% of average.

[f]110% of average.

[g]Figures are rounded.

TABLE 10-9. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Bremerton	169,500	36.00[a]	49.00	4.00	5.60
Port Townsend	40,000	9.20	12.90	—	—
Shelton	40,000	—	—	9.20	12.90
Port Orchard	20,000	—	—	4.60	6.40
Poulsbo, Winslow, Gig Harbor, and other rural community systems	120,000	2.80[b]	3.90	25.00	35.00
Subtotal	389,500	47.00	65.80	42.80	59.90
RURAL-INDIVIDUAL USE	43,200	—	—	4.80[c]	6.70
INDUSTRIAL USE					
Bremerton					
Naval Shipyard	—	7.00	7.50	1.50	1.60
Port Townsend					
Food and kindred[d]	—	0.06	0.09[e]	—	—
Paper and allied	—	36.00	40.00[f]	—	—
Shelton					
Lumber and wood	—	—	—	0.35	0.38[f]
Paper and allied	—	—	—	0.20	0.22[f]
Self-supplied:					
Paper and allied	—	36.00	40.00[f]	5.00	5.50[f]
Lumber and wood	—	0.70	0.80[f]	—	—
Food and kindred	—	—	—	0.11	0.16
Stone, clay, glass	—	0.19	0.19	—	—
Subtotal	—	79.95	88.60	7.20	7.90
Total[g]	432,700	127.00	154.40	54.80	74.50

[a]Estimated 90% to be served by surface sources in 1980, 95% in 2000 and 2020.

[b]Based on 1965 breakdown—10% surface water estimated for 1980-2020.

[c]Based on 110 gpcd and 100% rural individual population served by ground water by 1980.

[d]Production levels projected to be 167% of present level by 1980, 335% by 2000, and 720% by 2020. Water use projected to be 150% of present by 1980, 300% by 2000, 550% by 2020.

[e]150% of average.

[f]110% of average.

[g]Figures are rounded.

TABLE 10-10. Summary of projected water needs

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum montly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	103,750	7.3	11.6	7.1	14.6	14.4	26.2
	1980	148,800	15.1	21.1	13.2	18.5	28.3	39.6
	2000	246,700	28.8	40.5	22.9	32.1	51.7	72.6
	2020	385,900	47.0	65.8	42.8	59.9	89.8	125.7
Industrial	1965	—	30.6	42.5	3.2	3.8	33.8	45.3
	1980	—	58.3	64.7	4.5	4.9	62.8	69.6
	2000	—	77.8	86.4	6.6	7.4	84.4	93.8
	2020	—	80.0	88.6	7.2	7.9	87.2	96.5
Rural-Individual	1965	18,150	0.1	0.1	0.9	1.3	1.0	1.4
	1980	26,200	–	–	1.8	2.6	1.8	2.6
	2000	27,400	–	–	2.5	3.5	2.5	3.5
	2020	43,200	–	–	4.8	6.7	4.8	6.7
Totals	1965	121,900	38.0	54.2	11.2	19.7	49.2	73.9
	1980	175,000	73.4	85.8	19.5	26.0	92.9	111.8
	2000	274,100	106.6	126.9	32.0	43.0	130.6	169.9
	2020	432,700	127.0	154.4	54.8	74.5	181.8	228.9

Notes: All figures are rounded.

Municipal

Municipal water requirements, presently averaging 14.4 mgd annually, are expected to reach 28.3 mgd by 1980, 51.7 mgd in 2000, and 90 mgd by 2020. By the year 2020, municipal water needs will have risen from 30 percent of total water requirements to 50 percent. Per capita usage is expected to increase from 148 gpd at present to 190 gpd in 1980, 202 gpd in 2000, and 230 gpd in 2020. The greatest needs will be evident in the Kitsap Peninsula area and, particularly, on Bainbridge Island, if a cross-sound bridge provides adequate commuter means.

Industrial

Projections of industrial requirements indicate that industries will continue to require a lesser percentage of the total needs in the basin, although needs will increase from 33.8 mgd at present to 87.2 mgd by 2020. Industrial demand will be greatest in the pulp and paper industries at Shelton and Port Townsend.

Rural-Individual

By the year 2020, rural-individual needs are expected to be 4.8 mgd, or less than 3 percent of the total projected water needs in the basin. This percentage shows little change from present needs.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 177 mgd by the year 2020. This is an increase of approximately 128 mgd over the 1965 average use. Optimum or peak water requirements will be approximately two times this average or nearly 350 mgd. Tables 2-10 or 2-11, the Area Plans, summarize the basins' annual average and optimum requirement in relation to the remainder of the Area. Table 10-11, M&I Water Supply Needs, reviews the needs of the major water systems and/or users in the basin.

Bremerton, Port Townsend, and Shelton are and will continue to be the centers of commerce and urban development in the West Sound Basins. Together these three communities supply half the people and the municipally-supplied industry with 50 percent of the water used. The remaining 50 percent is consumed by smaller community systems and self-supplied industry, evenly.

The city of Bremerton's water system is, in all respects, the largest and most important in the Basin. If fully utilized, the available firm water supply could furnish 100 mgd, adequate for projected needs of the city and contiguous area past the year 2020. In addition to its Casad Dam and reservoir on the Union River, and its wells, the city has further surface water availability on the Tahuya and Hamma Hamma Rivers.

Port Townsend receives its water from the Big Quilcene River. The present gravity system is supplying 17 mgd, and can be further developed to meet future needs. This water is of sufficient quality to not require treatment. The Crown Zellerbach plant near Port Townsend is and will continue to be self-supplied.

Shelton, using ground water, develops adequate supplies which with continued development of this source will be capable of meeting all future demands through 2020.

The remaining communities currently have adequate supplies to meet existing needs. However, some areas are notably short on future water supplies. These are Bainbridge Island and areas on the northern part of the Kitsap Peninsula.

The optimum requirement, 350 mgd, is within the potential of the basin without conflict over withdrawals. No need for water from outside the basin is apparent. Urban growth, if it becomes intense enough, will bring about sufficient population density to make a county service or regional (PUD) water supply and transmission system feasible.

Future population growth will be extremely dependent upon future land use, highway and transportation routes and bridges, and not upon water supplies.

Table 10-11 shows present and future needs within the West Sound Basins for the major water distribution systems.

TABLE 10-11. M&I Water Supply-Capital Improvements
West Sound Basins

	Present 1965	1965-1980	Future 1980-2000	2000-2020
Population Served	42,000	70,000	116,700	169,500
BREMERTON				
Optimum	30.9	50.6	83.7	121.1
Capital Improvements	7.9	19.7	33.1	37.4
Population Served	7,500	12,000	25,000	40,000
PORT TOWNSEND				
Optimum	20.2	37.9	56.5	66.5
Capital Improvements	3.5	17.7	18.6	10.0
Population Served	5,800	12,000	25,000	40,000
SHELTON				
Optimum	4.5	8.5	17.1	27.0
Capital Improvements	2.8	4.0	8.6	12.9
Population Served	5,600	10,000	15,000	20,000
PORT ORCHARD				
Optimum	3.3	6.6	9.9	13.2
Capital Improvements	2.9	3.3	3.3	3.3
Population Served	43,540	44,800	65,000	120,000
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	28.6	29.6	42.7	79.2
Capital Improvements	23.6	1.0	13.1	36.5
Population Served	—	—	—	—
SELF SUPPLIED INDUSTRY				
Optimum	27.2	34.7	46.4	46.7
Capital Improvements	10.5	7.5	11.7	0.3
Population Served	104,440	148,800	246,700	389,500
TOTAL				
Capital Improvements	51	53	88	100

BASIN PLANS

The Selected Basin Plans for the West Sound Basins (Table 10-12) indicate future development will be along the lines of existing systems. This continued development calls for the use of surface water by Bremerton and Port Townsend, and local ground water developments by Shelton, Port Orchard and the remaining small and rural community systems. Table 10-12 includes a timetable of projected developments, cost of development and maintenance and operation plus expected annual income.

Storage and distribution costs, based on population growth, will be the same for the Basin Selected and Alternative Plans. These costs for the West Sound Basins, as well as for the remaining ten basins, are shown in the Area Selected and Alternative Plans, Tables 2-10 and 2-11, respectively.

Much of the West Sound Basins lacks only the important and necessary facilities of more urban areas to attract population and experience a moderate growth. Urban growth, if it becomes intense enough, will bring about sufficient population density to make a county service or regional water and transmission system feasible.

The Alternative Basin Plan has outlined somewhat of a regional service area to supply much of the southern part of the basin. This would happen if the Water Division, City of Tacoma, the PUD of a county or counties develops a surface water source on the South Fork of the Skokomish River. This would supply water to Shelton, across the south part of the basin to the Port Orchard vicinity, then across the Narrows Bridge to Tacoma.

TABLE 10-12. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan West Sound Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Optimum Capacity MGD: Supply	Optimum Capacity MGD: Transm.	1967 Thousand Dollars — Amortized Capital Cost[b]: Supply & Transm.	Amortized Capital Cost[b]: Treatment	Amortized Capital Cost[b]: Iron Removal	Maintenance and Oper.: Pumping Power	Maintenance and Oper.: Chem.	Total Annual Income
BREMERTON												
Present	SW	Union River, Gorst & Anderson Creeks	Exist.	9	23	23				101	3	1,168
Present	SW	Added Capacity 7.9	1975		8	8	1,040					
					31	31						
1980	SW	[a]Hamma Hamma River	1980	17	20	20	2,600			182	6	1,396
2000	SW	Added Capacity	1990	30	33	33	4,300			319	12	2,190
2020	SW	Added Capacity	2010	48	37	37	4,800			499	19	3,504
BREMERTON SELECTED PLAN TOTAL					121	121	$12,740					
PORT TOWNSEND												
Present	SW	Big Quilcene River	Exist.	15	16.7	16.7				161		
Present	SW	ADD: 4.0mgd	1965		4	4	520				6	1,752
1980	SW	Big Quilcene River	1970	29	18	18	2,340			339	12	3,738
2000	SW	Big Quilcene River	1986	41	18	18	2,340			434	16	4,789
2020	SW	Big Quilcene River 2nd Diversion 10mgd	2010	45	10	10	2,210			537	20	5,957
PORT TOWNSEND SELECTED PLAN TOTAL					67	67	$ 7,410					
SHELTON												
Present	GW	Local Ground Water	Exist.	2	1.7	1.7				16		234
Present	GW	Local Ground Water ADD: 2.5mgd	1965		2.5	2.5	130					
1980	GW	Local Ground Water	1975	3	4	4	240			29		346
2000	GW	Local Ground Water	1995	6	9	9	540			62		701
2020	GW	Local Ground Water	2015	10	10	10	780			103		1,168
SHELTON SELECTED PLAN TOTAL					27	27	$ 1,690					
PORT ORCHARD												
Present	GW	Local Ground Water	Exist.	0.4	0.4	0.4				4		47
Present	SW	Local Ground Water ADD: 3.0mgd	1965		3.0	3.0	180				1	
1980	GW	Local Ground Water	1975	2	3.5	3.5	210			21	1	234
2000	GW	Local Ground Water	1995	3	3.5	3.5	210			34	1	360
2020	GW	Local Ground Water	2015	5	3.5	3.5	210			48	2	584
PORT ORCHARD SELECTED PLAN TOTAL					14	14	$ 810					
POULSBO & OTHER RURAL COMMUNITIES												
Present	GW	Local Ground Water	Exist.	5	4	4				53		584
Present	GW	Local Ground Water ADD: 17.0mgd	1965		24	24	1,020					
1980	GW	Local Ground Water	1975	9	9	9	450			89		1,061
2000	GW	Local Ground Water	1995	14	13	13	780			142		1,636
2020	GW	Local Ground Water	2015	28	36	36	2,160			294		3,270
POULSBO & OTHER RURAL COMMUNITIES SELECTED PLAN TOTAL					79	79	$ 4,410					
SELF SUPPLIED INDUSTRY												
Present	SW	Local Surface Water	Exist.	14	14	14				147		5
	GW	Local Ground Water	1965	2	2	2				21		
1965	SW	Local Surface Water			11	11	1,430					
1980	SW	Local Surface Water	1975	28	4	4	520			338		10
	GW	Local Ground Water		4	4	4	240					
2000	SW	Local Surface Water	1995	37	8	8	1,040			441		13
	GW	Local Ground Water		5	4	4	240					
2020	SW	No Additional Need	2015	37								
	GW	No Additional Need		5						441		13
SELF SUPPLIED INDUSTRY SELECTED PLAN TOTAL					47	47	$ 3,470					
SELECTED BASIN PLAN TOTAL							$30,530					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 10-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan West Sound Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS: AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
BREMERTON												
Present	SW	Union River–Gorst Creek, etc.	Exist.	9	23	23				101	3	1,168
		[a] Duckabush River–Diversion Dam *(No Storage)*	1970		16	16	2,080			21		
						39	39					
1980	SW	Duckabush New Storage Dam & Reservoir	1976	17	83	83	12,000			400	6	1,396
2000	SW	(Above Diversion)	1990	30							12	2,190
2020	*SW*	*1,050 ac. ft.*	*2010*	48							19	3,504
BREMERTON ALTERNATIVE PLAN TOTAL					122	122	$14,080					
PORT TOWNSEND (Same as Selected Plan)												
SHELTON												
Present	GW	Local Ground Water	Exist.	2	1.7	1.7				16		234
Present	GW	Local Ground Water ADD: 2.5mgd	1965		2.5	2.5	130					
1980	SW	[a] Skokomish River	1975	3	4	4	520			29		345
2000	SW	Skokomish River	1995	6	9	9	1,170			62		701
2020	SW	Skokomish River	2015	10	10	10	1,690			103		1,168
SHELTON ALTERNATIVE PLAN TOTAL					27	27	$3,510					
PORT ORCHARD												
Present	GW	Local Ground Water	Exist.	0.4	0.4	0.4				4		47
Present	GW	Local Ground Water ADD: 3.0mgd	1965		3	3	180					
1980	SW	[a] Purchase from Tacoma Water Department	1980	2	3	3	390	240		21		234
2000	SW	Purchase from Tacoma Water Department	2000	3	3	3	390	247		34		350
2020	SW	Purchase from Tacoma Water Department	2020	5	4	4	494	248		48		584
					13	13	$ 1,454	$ 735				
PORT ORCHARD ALTERNATIVE PLAN TOTAL							$2,189					
POULSBO & OTHER RURAL COMMUNTIIES (Same As Selected Plan)												
SELF SUPPLIED INDUSTRY (Same as Selected Plan)												
ALTERNATIVE BASIN PLAN TOTAL							[c] $27,659					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

Some of the northern systems will combine as population density increases. The Plan calls for Bremerton to develop a new source on the Duckabush River across Hood Canal. Port Townsend will continue serving its consumers with fresh water from the Big Quilcene River.

Supply and transmission and storage and distribution costs for the Alternative Basin Plans are shown in Tables 10-13 and 2-11, respectively.

Surface and ground water supplies can be economically utilized by rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Table 10-11, Summary of Projected Water Needs, shows the level of need to 2020 from all sources.

FINANCE

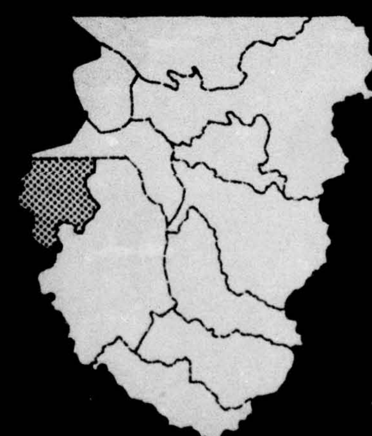
Annual income as taken from Tables 2-10 and 2-11 for the Selected Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

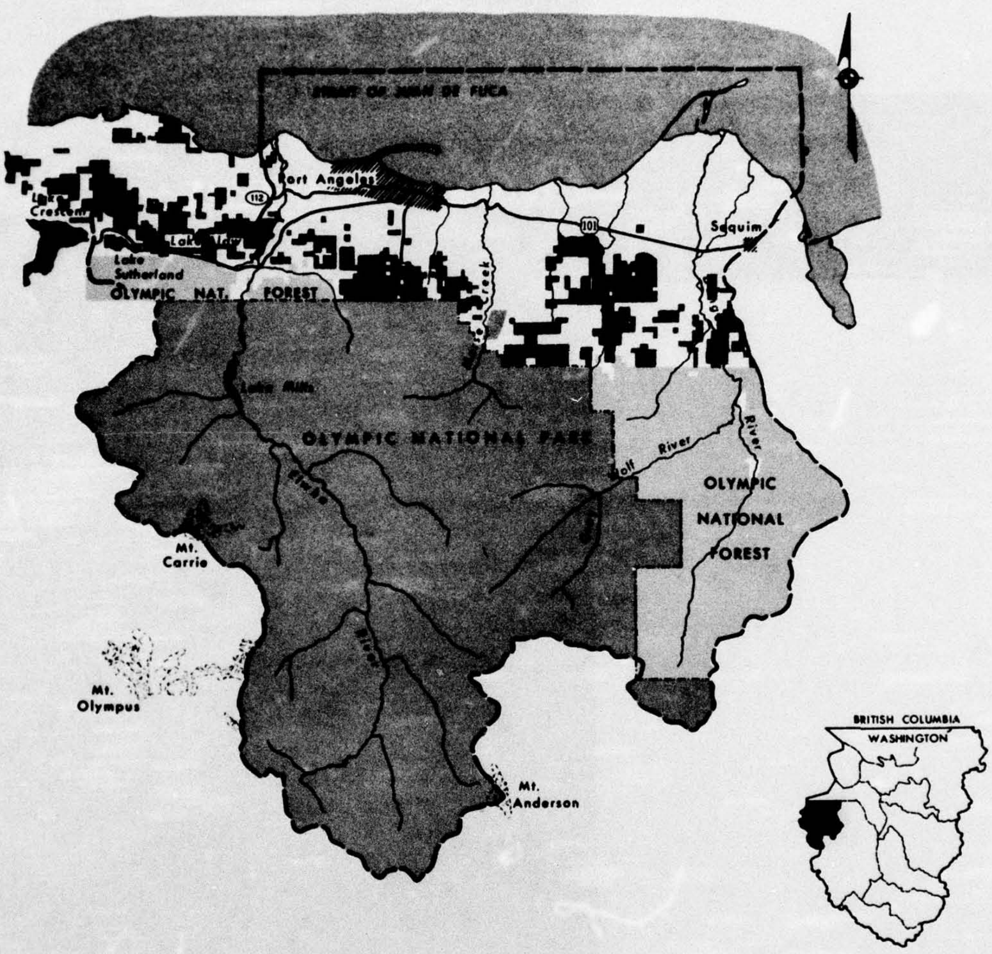
The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

		Annual Amortized Cost (x $1,000)	
Year	Annual Bond Service Available (x $1,000)	Selected Plan	Alternative Plan
1965	$810	$360	$380
1980	1,450	740	1,000
2000	2,070	1,470	1,280
2020	3,100	1,960	1,770

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that by 1980 or sooner the West Sound Basins may be unable to bond for the required water supply development, and future construction would involve extraordinary financial burden in relation to the Basin's economic resources unless water rates are raised.

Elwha-Dungeness Basins





LEGEND

- U.S. FOREST SERVICE
- STATE DEPARTMENT OF NATURAL RESOURCES
- NATIONAL PARK SERVICE
- MILITARY RESERVATION
- CITIES

Scale in Miles

5 0 5 10

ELWHA-DUNGENESS BASINS

Figure II-1 Land Ownership

ELWHA-DUNGENESS BASINS

INTRODUCTION

The Elwha-Dungeness Basins, westernmost basin in the Puget Sound Area, is located in Clallam and Jefferson Counties on the northern side of the Olympic Peninsula. (See figure 11-1.) The basin is bounded on the north by the Strait of Juan de Fuca, on the west by the crest of the Olympic Mountain Range, and on the southeast by the West Sound basin. The basin encompasses Port Angeles, the major city in the basin, and the rather thickly populated Sequim and Dungeness communities.

Population and industrial growth of the basin has been gradual and fairly steady over the past century, and this trend can be expected to continue past the year 2000. The available fresh water supply should be adequate through that time.

GEOGRAPHY

The basin is characterized by rugged mountains (photo 11-1), alpine meadows, and rain forests of the Olympic range, sloping northward to shelf-like plains 2 to 6 miles wide, and ending at the south shores of the Strait of Juan de Fuca.

The major water courses of the basin are the Elwha River and the Dungeness River. The Elwha River, about 40 miles long from its headwaters near Mount Olympus to its outlet in the strait, drains the western portion of the basin. The eastern portion is drained by the Dungeness River. This river, about 30 miles long, is glacier-fed, with headwaters between Mount Deception (7,788 feet) and Mount Constance (7,743 feet). It runs into the strait near the town of Dungeness. The area between these two major rivers is drained by many short, swift streams, the major one of which is Morse Creek.

There are three major lakes in the Elwha-Dungeness: Lake Sutherland (361 acres) and two man-made reservoirs, Lake Aldwell (321 acres) and Lake Mills (451 acres). The remaining basin lake areas (approximately 265 acres) are composed of numerous small lakes in the lowlands and cradles in the alpine areas.

CLIMATE

As can be expected in all areas adjacent to a large body of water and having extremes of elevation, the basin has a wide range of temperatures and rainfall. The low-lying populated areas along the coast have a mild climate with a fairly narrow temperature range. Ground fog is common to areas next to the strait. Because of the so-called Olympia rain shadow, the basins have a wide range of annual rainfall. Average annual precipitation in the Sequim-Dungeness area, about 75 percent of which falls during October through March, is approximately 17 inches, and may reach 240 inches a year in the higher mountains. Rainfall in the basin averages 77 inches per year, but is significantly less in the lowlands. Thus, while the southern part of the basin is one of the wettest places in the United States, the area in the rain shadow is semiarid and requires extensive irrigation for crops and pastureland.

POPULATION

About 28,500 persons live in the Elwha-Dungeness Basins. The two major population centers are Port Angeles, with 15,700 persons in 1965 and Sequim with 1,400 persons. Most settlement has occurred along the narrow coastal area, while the more rugged and inaccessible southern part remains barren of people. In addition to population growth engendered by industrial growth, retirement population is expected to increase steadily for the next 50 years.

ECONOMY

The economy of the basin is based primarily on manufacturing, government, trade, and agriculture. Paper and pulp production is the mainstay of basin economy. Lumber and pulp mills at Port Angeles and sawmills at Sequim sustain the local economy and provide seasonal employment for many part-time

PHOTO 11-1. The northern gateway into the Olympic Mountains is in the Elwha-Dungeness basin.

farmers. The average monthly employment for Clallam County in 1963 showed:

Agriculture	800
Mining	0
Construction	256
Manufacturing	3,100
Transportation, communication, and utilities	280
Trade (wholesale and retail)	1,300
Finance (insurance and real estate)	175
Service	685
Government	1,500
Not classified	70

Port Angeles, the Clallam County seat, has 56 manufacturing firms, principal products of which are lumber, newsprint, rayon, pulp, fiberboard products, shakes, and shingles. The excellent harbor formed by Ediz Hook provides facilities for loading and unloading coastal and ocean-going freighters. Log exports, mainly to Japan, are increasing, and the Port Angeles Port Authority is doing more business each year.

The Sequim-Dungeness area is devoted chiefly to agricultural activities. Lots of sunshine, an absence of destructive winds, and a lengthy growing season make this area agriculturally favorable. Extensive irrigation has made this one of the richest dairy centers in the State. Dairying and livestock are the primary farm enterprises, but some crops are grown. Hay and pasture crops, grain, berries, and seed crops make up the major land use of the irrigable areas. Dairying, livestock, and field crops account for over three-fourths of all farm products sold annually.

Tourism is the fastest growing industry in the basin because of the wide variety of scenic and recreational areas. Olympic National Park vies with Mount Rainier National Park as a tourist attraction and recreational area. Many tourists pass through the basin on their way around the scenic peninsula drive. Others use Port Angeles as a jumping off place on their way to Victoria, B.C. This tourist trade has encouraged the building of numerous business establishments for furnishing services and consumer goods to tourists.

The Sequim-Dungeness area, because of its mild, rain-free climate and its reasonable proximity to the Seattle metropolitan area, has attracted an increasing number of people at retirement age, and is expanding the permanent population of the basin. This buildup brings with it the need for more service and supply industries.

LAND USE

The Elwha-Dungeness Basins contain 448,000 acres of land and inland water. Forest lands predominate, accounting for 85 percent of the total land. Most of this acreage lies in the southern mountainous part, which is under Federal ownership (Olympic National Park and Olympic National Forest). Land

cleared for crops or pasture comprises the second largest land area in the Basin. A appreciable amount of acreage, about 4 percent, is converting to urban buildup where densities in excess of three houses per 10 acres occur. The land use of the Basin is given in Table 11-1.

TABLE 11-1. General land use.

Use	Acres
Forestland	409,000
Cropland	24,000
Rangeland	2,000
Other land (high, barren)	5,000
Urban buildup	6,000
Inland water	2,000
Total land and inland water	448,000

Source: Appendix III, Hydrology.

PRESENT STATUS

WATER USE

Total municipal and industrial water use in the basin amounts to more than 64 million gallons per day. This withdrawal of water from rivers, streams, springs, and wells in the basin serves a population of 28,500 persons. Water use is summarized in Table 11-2.

Municipal

More than 18,000 municipal consumers in the basin use an average of 46.2 mgd, 7 percent of total water use in the basin, and an average per capita use of 256 gpd. Some 15,700 municipal consumers in Port Angeles use about 3.8 mgd, an average per capita use of 242 gpd, and account for nearly 82 percent of total daily municipal water use. The more than 2,500 municipal consumers in Sequim and other rural communities use an average of 0.84 mgd, a per capita use of nearly 340 gpd.

Industrial

Industry uses more than 90 percent of all water used in the basin. Three pulp mills in Port Angeles use an average of more than 50 mgd. The Rayonier Incorporated pulp plant, largest industrial consumer in the basin, uses an average of 35.7 mgd, more than 60 percent of the industrial water and 55 percent of all water used in the basin. The second largest industrial user is the Crown Zellerbach pulp mill which uses some 18 mgd. The Fiberboard Corporation pulp mill uses an average of 5.0 mgd.

Rural-Individual

An estimated 10,500 rural consumers use an average of 0.55 mgd, a per capita use of slightly less than 55 gpd representing less than 1 percent of total basin water use.

WATER SUPPLIES

The Elwha and Dungeness Rivers plus numerous creeks, springs, and wells currently supply municipalities, industry, individuals, private water companies, public utility districts, and water associations. Both surface and ground waters are used to meet the average daily requirement of 64.3 million gallons. Ground water furnishes 0.5 mgd.

Municipal

The city of Port Angeles obtains water for its municipal supply from Morse Creek. The system consists of a simple diversion dam, which currently supplies the city with 3.80 million gallons daily, but is capable of supplying a peak demand of 8.10 mgd; it serves a population of 15,700 and, periodically, one industry. The water is disinfected for domestic use. Figure 11-2 shows water use from 1952 to 1966.

The average municipal monthly demand profile for Port Angeles from 1961 through 1966 is shown on figure 11-3. The summer months, as expected, have the biggest demand.

Sequim obtains its domestic water from an infiltration gallery adjacent to the Dungeness River. The average needs supplied by this system total 0.75

TABLE 11-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Maximum daily	Ground water usage (mgd) Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Port Angeles	15,700	3.78	7.10	11.00	---	---	---
Hoks Waterwell	560	0.05	0.10	0.14	---	---	---
Sequim	1,400	0.75	1.00	1.50	---	---	---
Rural community systems	340	0.01	0.01	0.01	0.03	0.04	0.06
Subtotal	18,000[b]	4.59	8.21	12.65	0.03	0.04	0.06
RURAL-INDIVIDUAL USE	10,500	0.05[a]	0.07	0.10	0.50[a]	0.70	1.00
INDUSTRIAL WATER USE							
Municipally supplied:							
Port Angeles							
Paper and allied (fibreboard)		0.20	2.10	2.50	---	---	---
(Crown Z.)		0.09	0.10	0.10	---	---	---
(Rayonier)		0.17	0.20	0.20	---	---	---
Self-supplied:							
Paper and allied		58.70	62.50	66.00	---	---	---
Fibreboard		(5.00)	(5.50)	(6.00)	---	---	---
Crown Zellerbach		(18.00)	(19.00)	(20.00)	---	---	---
Rayonier		(35.70)	(38.00)	(40.00)	---	---	---
Subtotal		59.16	64.90	68.80	---	---	---
Total	28,500	63.90	73.20	81.60	0.50	0.70	1.10

[a]Based on 55 gpcd and 90 percent of rural individual population served by ground water.

[b] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

mgd, which serve a population of 1,400 persons. The site is owned by the city, is free of nearby sources of pollution, and the supply is chlorinated prior to delivery. Capacity of the present source development is 0.9 mgd which is more than adequate for present needs.

More than 340 persons are served by several rural community systems which supply about 0.04 mgd. Approximately 0.01 mgd are supplied from ground sources; the remainder is supplied from surface sources.

Industrial

A 70-inch industrial water line constructed by the city of Port Angeles in 1929 to divert water from the Elwha River furnishes 59 mgd to the Crown Zellerbach Fiberboard Corporation, and I.T.T. Rayonier Incorporated pulp mills. The facility is owned by the city of Port Angeles but is operated and maintained by the industries. Although the line was constructed to relieve industrial demands on the municipal system, the Fiberboard Corporation pulp mill draws an average of 0.50 mgd from the municipal system when waters of the Elwha are unsatisfactory for its use. Although average annual demand by this industry is 0.50 mgd, most of the water is used during the winter months when waters of the Elwha are turbid, which reflects a somewhat higher municipal use during December and January than would be expected for purely municipal consumption.

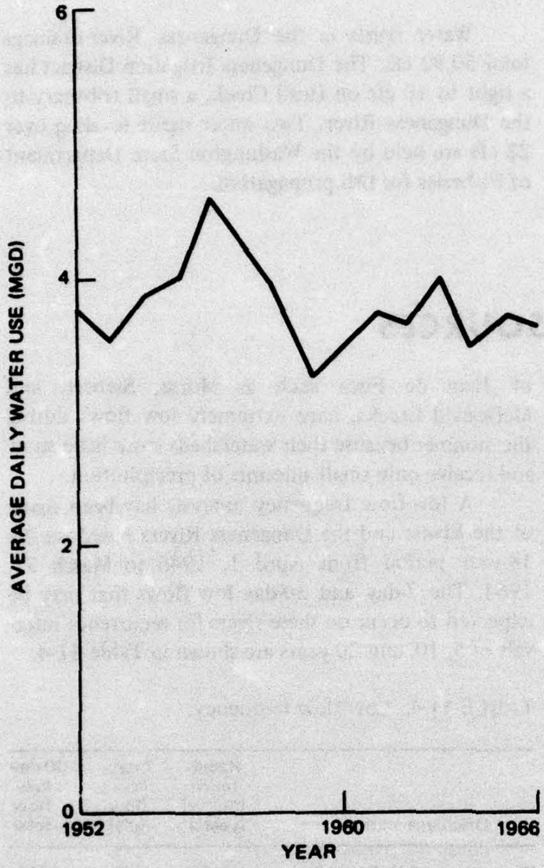


FIGURE 11-2. Port Angeles water consumption.

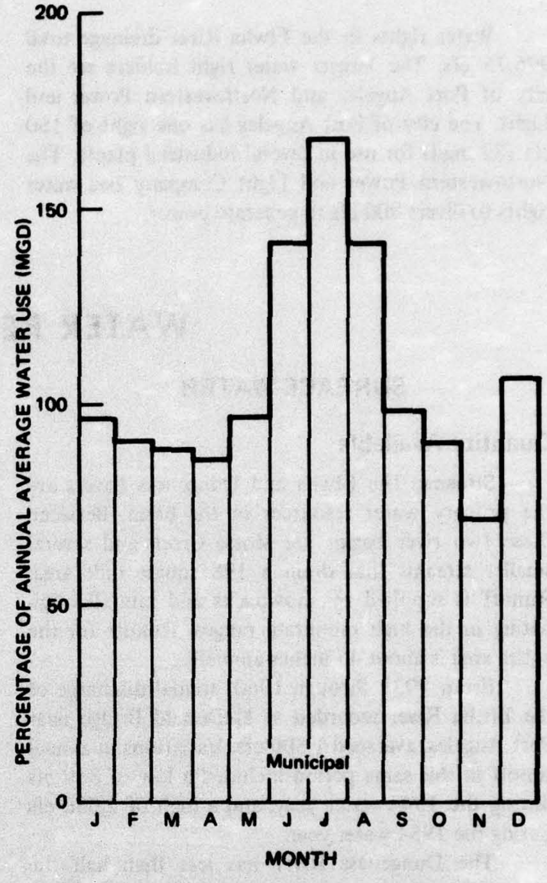


FIGURE 11-3. Port Angeles water use profile.

Rural-Individual

An estimated 10,500 persons are served by about 3,700 rural-individual systems. Most of these systems (95 percent) are supplied by ground waters that are generally satisfactory in sanitary quality. Approximately 200 systems use surface supplies, which for the most part are unsatisfactory.

WATER RIGHTS

Surface water rights in the Elwha-Dungeness Basins (through December 31, 1965) for municipal, industrial, and domestic water supply and irrigation purposes, are summarized in Table 11-3. Water rights include applications for diversions totaling over 1,047.67 cfs (677 mgd). Temporary permits have been granted to nine of these applicants in the amount of 2.24 cfs (1.45 mgd). Sixty certified or permanent water rights have been issued for approximately 994.51 cfs (634 mgd).

TABLE 11-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Appropriative:			
Surface water	20.2	9.5	122.8
Ground water	1.0	8.7	0.3
Subtotal [a]	21.2	18.2	123.1
Adjudicated	—	374.1	—
Total	21.2	392.3	123.1

[a]About 448 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

Water rights in the Elwha River drainage total 996.75 cfs. The largest water right holders are the city of Port Angeles and Northwestern Power and Light. The city of Port Angeles has one right of 150 cfs (82 mgd) for use in several industrial plants. The Northwestern Power and Light Company has water rights to divert 800 cfs to generate power.

Water rights in the Dungeness River drainage total 50.92 cfs. The Dungeness Irrigation District has a right to 10 cfs on Hurd Creek, a small tributary to the Dungeness River. Two water rights totaling over 28 cfs are held by the Washington State Department of Fisheries for fish propagation.

WATER RESOURCES

SURFACE WATER

Quantity Available

Streams The Elwha and Dungeness Rivers are the primary water resources in the basin. Between these two river basins are Morse Creek and several smaller streams that drain a 198 square mile area. Runoff is supplied by snowpacks and rainfall originating in the high mountain ranges. Runoff for the entire area is about 45 inches annually.

From 1931 through 1960, annual discharge of the Elwha River recorded at McDonald Bridge near Port Angeles, averaged 1,500 cfs. Variations in annual runoff in this same period included a low of 859 cfs during the 1944 water year, and a high of 2,050 cfs during the 1954 water year.

The Dungeness River has less than half the volume runoff of the Elwha, which reflects its lower elevation and location in the rain shadow of the Olympic Peninsula. Records for the Dungeness show an annual average discharge of about 382 cfs during the 30-year period from 1931 through 1960. The minimum recorded discharge at the USGS stream gage near Sequim was 200 cfs during the 1944 water year, and the maximum was 549 cfs in 1954.

These two rivers share similar seasonal runoff variations. Flows in both the Elwha and Dungeness peak during the winter period of high precipitation, and again in late spring or early summer under a combination of spring rains and snowmelt. Generally, the greatest monthly flows occur in May and June. By contrast, winter flows are more variable and are often characterized by sharp rises caused by storms.

Both the Elwha and Dungeness exhibit minimum flows during the summer when precipitation is least and snowpacks are depleted. Following the spring rains and the snowmelt peak, streamflow recedes to minimum base flow, usually by the end of September. All of the smaller tributaries to the Strait of Juan de Fuca such as Morse, Siebert, and McDonald Creeks, have extremely low flows during the summer because their watersheds store little snow and receive only small amounts of precipitation.

A low-flow frequency analysis has been made of the Elwha and the Dungeness Rivers based on the 18-year period from April 1, 1946 to March 31, 1964. The 7-day and 30-day low flows that may be expected to occur on these rivers for recurrence intervals of 5, 10, and 20 years are shown in Table 11-4.

TABLE 11-4. Low-flow frequency.

Discharge station	Recurrence interval (years)	7-day low flow (cfs)	30-day low flow (cfs)
Elwha River at McDonald	5	340	415
Bridge near Port Angeles	10	300	375
	20	260	340
Dungeness River near Sequim	5	104	120
	10	96	109
	20	88	101

Dams and Impoundments. There are two dams and storage reservoirs on the Elwha River. This river has been partly regulated at Lake Aldwell since 1911 and at Glines Canyon Dam (Lake Mills) since 1927. These two private power developments have a combined total storage of 69,000 acre-feet. Their combined active storage of 29,000 acre-feet is used primarily to meet power demands, but some storage is used to augment low flows for fish enhancement. No reservoir exists on the Dungeness River.

Lakes. The total amount of storage in lakes and glaciers in the basins is not known, but the total surface area covered by water bodies is about 2.2 square miles, of which about 1.6 square miles comprise regulated waterbodies.

Quality

The quality of surface water in the Elwha-Dungeness Basins is excellent in virtually all respects. (See table 11-5.) The major rivers and streams in this basin flow the greater part of their length through a natural sanctuary, Olympic National Park. Outdoor recreation is the principal use of the undeveloped watersheds.

Water quality of the Elwha and Dungeness Rivers has been measured for 9 years on a monthly basis from July 1959 to July 1960, and then quarterly thereafter to 1966. The following data were gathered from monitoring stations located on the Elwha at McDonald Bridge near Port Angeles and on the Dungeness near Sequim.

Physical. Maximum temperatures of both the Elwha and Dungeness is generally low in comparison to other streams in the Puget Sound Area. Temperatures on the Elwha have reached a maximum recorded value of only 15.5° C (59.9° F). A maximum of 16.1° C (61° F) has been recorded on the Dungeness River. The Elwha is generally 1° to 4°F warmer than the Dungeness during most months. This warmer temperature may be in part attributed to the stabilizing effects of Lake Mills.

The lower maximum temperature of these two streams is caused by the predominantly high altitude and northern latitude of their watersheds. These streams are also among the few in the Puget Sound Area that are north-south oriented, and thus are less subject to warming by the sun.

Except during high-runoff periods, the Elwha and Dungeness Rivers run clear. Usually, the turbidity for the Elwha is 12 and the Dungeness 7 JTU. A maximum turbidity of 65 JTU for the Dungeness and 60 JTU for the Elwha was recorded. These two streams are generally free from suspended sediment. Color values range from 0-15 units for the Dungeness and 0-10 units for the Elwha. The average color value for both rivers is well below the recognized standard of 15 for drinking water.

The Elwha River transports about 25,000 tons of sediment during a year of normal streamflow. In contrast, the Dungeness River transports less than 1,000 tons of sediment in an average year. Suspended sediment concentration in most streams of the basin is usually less than 20 mg/l.

Chemical. Concentrations of total dissolved solids in the rivers and streams rarely exceed 85 mg/l. The Elwha and Dungeness rivers and their major tributaries are swift-flowing streams, and dissolved oxygen concentrations throughout the length of these rivers are near saturation. DO concentrations on the Elwha range from a low recorded value of 10.0 mg/l to a high of 14.1 mg/l. The DO concentrations on the Dungeness range from 8.5 mg/l to 13.5 mg/l.

Bacteriological. The sanitary quality of these streams is excellent. Data indicate that MPN values of coliform bacteria are usually less than 100. On the Elwha, the MPN ranges from a low of 0 to a maximum value of 430. The MPN values on the Dungeness range from 0 to 230 coliforms.

GROUND WATER

Quantity Available

Plentiful supplies of ground water are found in several mountainous and lowland regions of the Elwha-Dungeness Basins. Virtually all of the ground water in the lowlands is drawn from sands and gravels deposited by the northward flowing streams or by glacial action. Generally, this material is permeable

TABLE 11-5. Surface water quality.

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2) (mg/l)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		mg/l	mg/l	mg/l							mg/l		mg/l	mg/l	
ELWHA RIVER NEAR PORT ANGELES JULY 1959 THROUGH 1966																											
Maximum	6,600	67	16.0	1.7	2.3	0.6	61	0	9.2	1.0	0.3	0.3	108	0.11	---	7.8	0.62	0.03	8.0	10	60	15.5	14.1	116	46	6	430
Mean	---	54	13.4	1.0	1.8	0.2	41	0	7.5	0.7	0.1	0.1	86	0.02	---	6.1	0.16	0.01	---	---	---	9.2	11.6	104	38	4	23
Minimum	348	42	10.0	0.1	1.2	0.0	32	0	4.9	0.0	0.0	0.0	63	0.00	---	3.0	0.00	0.00	6.4	0	0	3.2	10.0	95	29	2	0
Number	25	28	28	28	28	28	28	15	28	28	28	28	28	27	---	28	27	11	28	28	14	29	27	27	28	28	29
DUNGENESS RIVER NEAR SEQUIM JULY 1959 THROUGH 1966																											
Maximum	1,300	94	23.0	3.9	4.1	0.6	79	0	10.0	2.2	0.2	0.6	152	0.06	---	14.0	4.40	0.04	7.9	10	65	16.1	13.5	114	69	5	230
Mean	---	70	16.9	2.3	2.7	0.3	60	0	7.2	1.1	0.1	0.2	115	0.01	---	6.5	0.46	0.01	---	---	---	9.2	11.2	101	52	2	42
Minimum	102	50	12.0	1.2	1.6	0.0	44	0	4.4	0.2	0.0	0.0	80	0.00	---	3.0	0.01	0.00	6.3	0	0	2.4	8.5	87	37	0	0
Number	25	29	29	29	29	29	29	16	29	29	29	29	29	27	---	29	27	12	29	29	10	29	27	27	29	29	29

enough to allow moderate yields of ground water. Some ground water areas are quite productive, and many wells are excellent producers capable of sustaining considerable production.

Natural precipitation is the chief source of recharge to the aquifers. Runoff from the Olympic Mountains may also contribute substantial amounts of recharge, as the annual precipitation in the Sequim-Dungeness area is low, but the ground water supply is quite abundant. Irrigation, which has caused a rise in the water table of as much as three feet in some areas during the summer months, is an important secondary source of recharge.

The amount of natural recharge to aquifers in the lowlands may be as much as 10,000 acre-feet per year. However, probably not more than one-half of this recharge can be intercepted by wells because of steep hydraulic gradients, which often exceed 100 feet per mile.

Quality

Only limited data on the quality of ground water in the basin are available. Information on chemical quality is confined primarily to chloride concentration and hardness. On the basis of 23 incomplete chemical analyses, chloride concentrations range from 2 to 30 mg/l but are generally less than 10 mg/l. Hardness ranges from 26 to 169 mg/l, but is more commonly between 60 and 120 mg/l. Ground water in the basin thus may be considered as moderately hard.

Objectionable concentrations of iron in water are occasionally reported from owners of shallow wells.

PRESENT AND FUTURE NEEDS

Principal factors that will determine water demand in the Elwha-Dungeness Basins are growth in the pulp and paper industry by 1980 and population growth and further industrial expansion, again mostly in the pulp and paper industry, from 1980 to 2000. Demand will increase also as a result of increased tourism and summer home development.

PROJECTED POPULATION GROWTH

Figure 11-4 shows projected population in the basin from 1965 through 2020. The 1965 population (28,500) will increase about 5 percent to 29,800 by 1980, about 44 percent to 41,000 by the year 2000, and 98 percent to 56,600 by 2020. Most of the increase is expected to occur in and around the urban Port Angeles area in keeping with the expected growth in the pulp and paper industry and recreational activity.

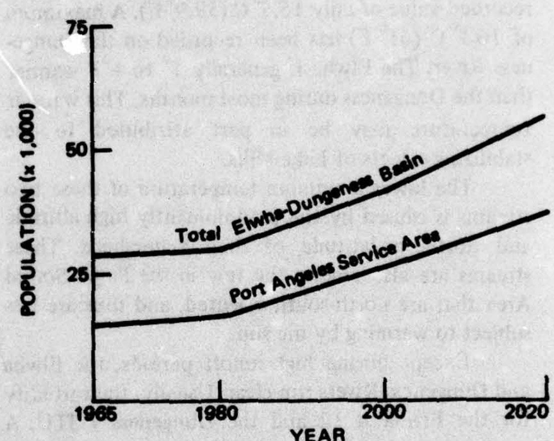


FIGURE 11-4. Projected population growth.

PROJECTED INDUSTRIAL GROWTH

Production growth of major water-using industries is projected to increase by 400 percent between the present and the year 2000. The major water-using industry will be the pulp and paper industry, with food processing nearly matching its rate of growth after the year 2000. As shown in Figure 11-5, these industries will by then account for nearly all the total value added by major water-using industries. (Value added represents wages and salaries, interest payments, rental payments, profit, and the like. The term "value added," as used here, represents industries' contribution to the gross basin product. It is used in this report to measure the production growth of industries.) The lumber industry is projected to remain at its present level of activity to the year 2020, without affecting water use.

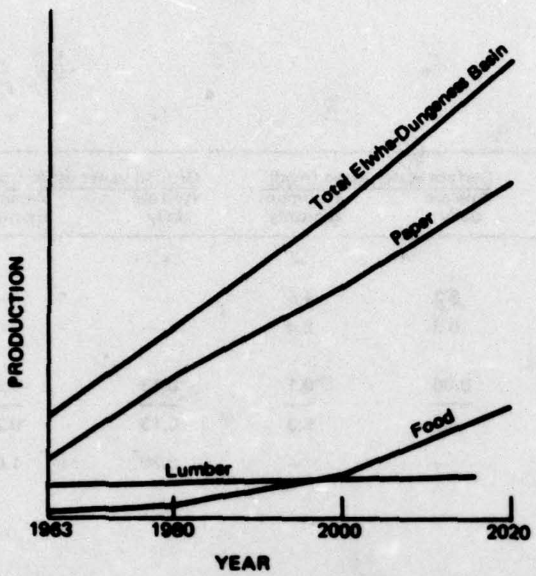


FIGURE 11-5. Relative production growth for major water-using industries.

PROJECTED WATER REQUIREMENTS

Total water requirements in the basin are expected to reach 271 mgd by the year 2020, an increase of more than 400 percent over present needs. Surface water sources will supply 99 percent of the projected needs. Tables 11-6, 11-7, and 11-8 itemize projected water use in 1980, 2000, and 2020, respectively. Table 11-9 summarizes water needs from the present through 2020.

Municipal

Municipal water requirements are expected to reach an annual average of 3.7 mgd by 1980, 6.0 mgd by 2000, and 9.8 mgd by 2020. This will amount to less than 4 percent of the total water needs in the basin. Per capita water consumption is expected to increase to about 190 gpd in 1980, to 220 gpd in 2000, and to 235 gpd in 2020. About 90 percent of the total basin municipal needs are expected to be supplied to the Port Angeles service area by 2020.

Industrial

Industrial water needs, presently 59.1 mgd, are expected to increase by 130 percent to 135 mgd by 1980, by 240 percent to 202 mgd by the year 2000, and by 340 percent to 259 mgd by 2020. Industrial water is expected to continue to be supplied predominantly to the pulp and paper industry, accounting for 95 percent of all water used by 2020. Water for food processing industries has been included in the municipal per capita water use figures.

Rural-Individual

Rural-individual use will double between 1980 and 2020 as a result of population growth and an increase in per capita consumption. However, the amount needed by 2020 (1.60 mgd) will be less than 1 percent of the total water needs of the basin.

TABLE 11-6. Projected water use (1980)

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Port Angeles service area	16,700	3.2	4.5	—	—
Sequim	1,600	0.3	0.4	—	—
Hoks Waterwell and other rural community systems	1,000	0.06	0.1	0.13	0.2
Subtotal	19,300	3.6	5.0	0.13	0.2
RURAL-INDIVIDUAL USE	10,500	—	—	0.70[a]	1.0
INDUSTRIAL WATER USE					
Port Angeles					
Paper and allied					
Fiberboard	—	0.3	3.0	—	—
Crown Zellerbach	—	0.2	0.3	—	—
Rayonier	—	0.3	0.4	—	—
Self-supplied:					
Paper and allied					
Fiberboard	—	11.2	12.3[b]	—	—
Crown Zellerbach	—	41.0	45.0[b]	—	—
Rayonier	—	82.0	90.0[b]	—	—
Subtotal	—	135.0	151.0	—	—
Total[c]	29,800	138.6	156.0	0.80	1.2

[a]*Based on 70 gpcd and 100 percent of rural individual population served by ground water by 1980.*

[b]110 percent of average.

[c]Figures are rounded.

TABLE 11-7. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Port Angeles service area	25,200	5.30	7.40	—	—
Sequim	2,000	0.40	0.60	—	—
Hoks Waterwell and other rural community systems	1,500	0.10	0.14	0.20	0.28
Subtotal	28,700	5.80	8.10	0.20	0.28
RURAL-INDIVIDUAL USE	12,300	—	—	1.10[a]	1.50
INDUSTRIAL WATER USE					
Port Angeles					
Paper and allied					
Fiberboard	—	0.50	4.00	—	—
Crown Zellerbach	—	0.40	0.50	—	—
Rayonier	—	0.50	0.60	—	—
Self-supplied:					
Paper and allied					
Fiberboard	—	17.00	18.70[b]	—	—
Crown Zellerbach	—	62.00	68.00[b]	—	—
Rayonier	—	122.00	134.00[b]	—	—
Subtotal	—	202.90	225.80	—	—
Total[c]	41,000	208.70	233.90	1.30	1.80

[a]Based on 90 gpcd and 100 percent of rural individual population served by ground water by 1980.

[b]110 percent of average.

[c]Figures are rounded.

TABLE 11-8. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Port Angeles service area	36,400	8.40	11.80	---	---
Sequim	4,000	0.90	1.30	---	---
Hoks Waterwell and other rural community systems	2,000	0.15	0.20	0.30	0.40
Subtotal	42,400	9.45	13.30	0.30	0.40
RURAL-INDIVIDUAL USE	14,200	—	—	1.60[a]	2.20
INDUSTRIAL WATER USE					
Port Angeles					
Paper and allied					
Fiberboard	—	0.80	5.00	---	---
Crown Zellerbach	—	0.60	0.80	---	---
Rayonier	—	0.80	1.00	---	---
Self-supplied:					
Paper and allied					
Fiberboard	—	20.00	22.00[b]	---	---
Crown Zellerbach	—	79.00	87.00[b]	---	---
Rayonier	—	158.00	174.00[b]	---	---
Subtotal	—	259.20	289.80	---	---
Total[c]	56,600	268.70	303.10	1.90	2.60

[a]Based on 110 gpcd and 100 percent of rural individual population served by ground water by 1980.

[b]110 percent of average.

[c]Figures are rounded.

TABLE 11-9. Summary of projected water needs.

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	18,000	4.6	8.2	0.0	0.0	4.6	8.2
	1980	19,300	3.6	5.0	0.1	0.2	3.7	5.2
	2000	28,700	5.8	8.1	0.2	0.3	6.0	8.4
	2020	42,400	9.5	13.3	0.3	0.4	9.8	13.7
Industrial	1965	42,400	59.2	64.9	--	--	59.2	64.9
	1980	—	135.0	151.0	--	--	135.0	151.0
	2000	—	202.9	225.8	--	--	202.8	225.8
	2020	—	259.2	289.8	--	--	259.2	289.8
Rural-Individual	1965	10,500	0.1	0.1	0.5	0.7	0.6	0.8
	1980	10,500	--	--	0.7	1.0	0.7	1.0
	2000	12,300	--	--	1.1	1.5	1.1	1.5
	2020	14,200	--	--	1.6	2.2	1.6	2.2
Totals	1965	28,500	63.9	73.2	0.5	0.7	64.4	73.9
	1980	29,800	138.6	156.0	0.8	1.2	139.4	157.2
	2000	41,000	208.7	233.9	1.3	1.8	210.0	235.7
	2020	56,600	268.7	303.1	1.9	2.6	270.6	305.7

Note: All usage figures are rounded to one decimal place.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 270 mgd by the year 2020. This is an increase of approximately 205 mgd over the 1965 average use. Optimum or peak water requirements will be nearly 350 mgd, approximately 130 percent of the average annual. Tables 2-12 or 2-13, the Area Plans, summarize the basins' annual average and optimum requirement in relation to the remainder of the Area. Table 11-10, M&I Water Supply Needs, reviews the needs of the major water systems and/or users in the basin.

Municipal and rural-individual water supplies are adequate to satisfy expected demand for the years 2000 and 2020. However, problems of quality, supply and system transmission and storage and distribution require improvement before adequate supplies can be developed during low-flow periods of recurrence of 10 years or more.

The Elwha River, from which the self-supplied industries presently take their water, is projected to be a satisfactory source to meet industrial demands through 2020. There is a basic need, however, for planned development of the area based on sound management policies to coordinate the competing industrial uses and to insure surface water supply adequacy if the Port Angeles municipal system should go to the Elwha River for increased supply, as is projected in the Alternative Plan, instead of developing this supply from ground water.

Port Angeles municipal water use is expected to increase from an existing 8.1 mgd to 30.8 mgd by the year 2020. The present source of supply, Morse Creek, is expected to be capable of meeting demands up to 26 mgd without additional water from the Elwha River. The industrial water requirements for Port Angeles in 2020 are projected to be more than nine times (283 mgd) the municipal use, and are expected to continue being supplied from the Elwha River. No other source is projected to be needed.

The present source of supply for Sequim consists of an infiltration gallery adjacent to the Dungeness River. Capacity of the present source development is 0.9 mgd which is more adequate for present needs. If necessary, direct diversion from the Dungeness River is possible.

TABLE 11-10. M & I Water Supply-Capital Improvements
Elwha-Dungeness Basins

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	15,700	16,700	25,200	36,400
PORT ANGELES				
Optimum	12.7	14.7	21.7	30.8
Capital Improvements	0.8	2.0	7.0	9.1
Population Served	1,400	1,600	2,000	4,000
SEQUIM				
Optimum	0.9	1.3	1.3	2.6
Capital Improvements	—	0.1	—	1.3
Population Served	900	1,000	1,500	2,000
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	0.6	0.7	1.0	1.3
Capital Improvements	0.4	0.1	0.3	0.3
Population Served	—	—	—	—
SELF SUPPLIED INDUSTRY				
Optimum	62.5	147.3	220.7	283.0
Capital Improvements	—	84.8	73.4	62.3
Population Served	18,000	19,300	28,700	42,400
TOTAL				
Capital Improvements	—	87	79	73

NOTE: Figures are rounded.

The rural–individual and smaller community requirements can be supplied by the relatively abundant ground waters in the lowlands. Except for localized areas of shortage or quality, adequate quantities of ground water are available within a reasonable depth to permit utilization of this resource.

BASIN PLANS

The Selected and Alternative Plans, Tables 11-11 and 11-12, will cost approximately $3.7 million and $5.4 million, respectively. The cost difference between the two is due to supply source development for the City of Port Angeles. The Selected Plan calls for the development of ground water supplies from aquifers in the lowlands near the city. The Alternative Plan is to develop surface water from the Elwha River and provide treatment. The remaining communities are projected to continue developing ground water under both plans. The self-supplied industry will also continue with present developments: this is surface water from the Elwha River.

One factor not presently considered is the ability of the pulp mills to reuse water or to use sea water for many cooling and air washing functions, thereby reducing fresh water demands.

The requirements for Port Angeles are to develop Morse Creek to its ultimate capacity, provide additional quality control facilities, system transmission, storage, and distribution improvements, and supply 5.0 mgd needs from Elwha River.

With construction by the City of Sequim of additional capacity and improvements to storage within the distribution system, the present water supply is adequate to satisfy the projected needs to the year 2020. This is also true of the self-supplied industry.

The total amount of basin needs are within the supply potential of the basin without conflict over withdrawals or importation of water from outside the basin.

Urban growth is not anticipated to bring about sufficient population density to make a county-service or regional water supply and transmission system feasible.

Surface and ground water supplies can be economically utilized by rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Table 11-10, Summary of Projected Water Needs, shows the level of need to 2020 from all sources. On this basis, a ground water source is recommended as the least expensive alternative, and still be adequate to satisfy the projected municipal needs.

FINANCE

Annual income as taken from Tables 2-10 and 2-11 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 21.5 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

Year	Annual Bond Service Available (x $1,000)	Annual Amortized Cost (x $1,000) Selected Plan	Alternative Plan
1965	$1,160	$ 84	$ 84
1980	2,470	42	110
2000	3,360	160	140
2020	4,330	190	220

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that the Elwha and Dungeness Basins will be able to bond for the required water supply development, and future construction without extraordinary and excessive financial burden in relation to the basins' economic resources.

TABLE 11-11. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Elwha-Dungeness Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
PORT ANGELES												
Present	SW	Morse Cr. Surf Diversion	Exist.	4	12.2	12.1				45	18	467
		No Present Needs										
1980	GW	Local GW	1975	4	3	3	186			42		467
2000	GW	Local GW	1995	8	7	7	420			70		934
2020	GW	Local GW	2015	11	9	9	546			96		1,285
PORT ANGELES SELECTED PLAN TOTAL					31	31	$ 1,152					
SEQUIM												
Present	GW	1.0mgd—No Present Needs	Exist.	0.8	1.0	1.0				5		93
1980	GW	Additional 0.4mgd (Add)	1975	0.4	0.4	0.4	24			5		47
2000	GW	No Future Needs		0.3						5		35
2020	GW	Additional 1.3mgd (Add)	2010	0.9	1.3	1.3	78			10		105
SEQUIM SELECTED PLAN TOTAL					3	3	$ 102					
RURAL & COMMUNITY SYSTEMS												
Present	GW	Local GW Development—0.2mgd	Exist.	0.1	0.2	0.2						12
		Present Needs			0.4	0.4	24			1		
					0.6	0.6						
1980	GW	Local GW Development—0.1mgd	1975	0.2	0.1	0.1	6			2		23
2000	GW	Local GW Development—0.3mgd	1995	0.3	0.3	0.3	18			3		35
2020	GW	Local GW Development—0.3mgd	2015	0.5	0.3	0.3	18			5		58
RURAL & COMMUNITY SYSTEMS SELECTED PLAN TOTAL					1.9	1.9	$ 66					
SELF SUPPLIED INDUSTRY												
Present	SW	Untreated Elwha River	Exist.	59	63	63				662		4,845
1980	SW	Untreated Elwha River-134	1970	134	86	86	1,000			1,543		11,005
2000	SW	Untreated Elwha River—201	1990	201	73	73	840			2,310		14,673
2020	SW	Untreated Elwha River—257	2010	257	62	62	566			2,972		18,761
SELF SUPPLIED INDUSTRY SLECTED PLAN TOTAL					283	283	2 406					
SELECTED BASIN PLAN TOTAL							$ 3,726					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 11-12. M & I Water Supply Use planning—Present to year 2020 Alternate Basin Plan Elwha-Dungeness Basins

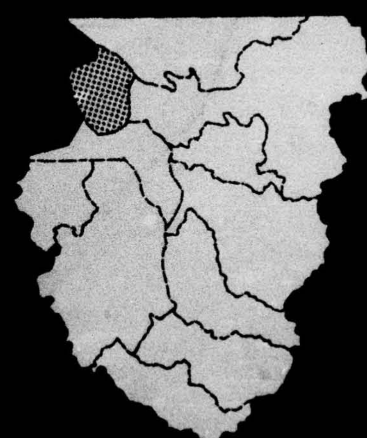
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
PORT ANGELES												
Present	SW	Morse Creek–Surf Diversion	Exist.	4	12	12				45	2	467
		No Present Needs										
1980	SW	Develop to Ultimate Capacity 13 mgd	1970	4	14	14	1,820			52	2	467
2000	SW	No Future Needs		8						70	3	434
2020	SW	[a]Elwha River Additional Treatment–5mgd	2010	11	5	5	650	375		111	4	1,285
					31	31	$2,470	$ 375				
PORT ANGELES ALTERNATIVE PLAN TOTAL							$2,845					
SEQUIM												
		No Feasible Second Alternative					102					
SMALL & RURAL COMMUNITY SYSTEMS												
		No Feasible Second Alternative					66					
SELF SUPPLIED INDUSTRY												
		No Feasible Second Alternative					2,406					
ALTERNATIVE BASIN PLAN TOTAL							$5,419					

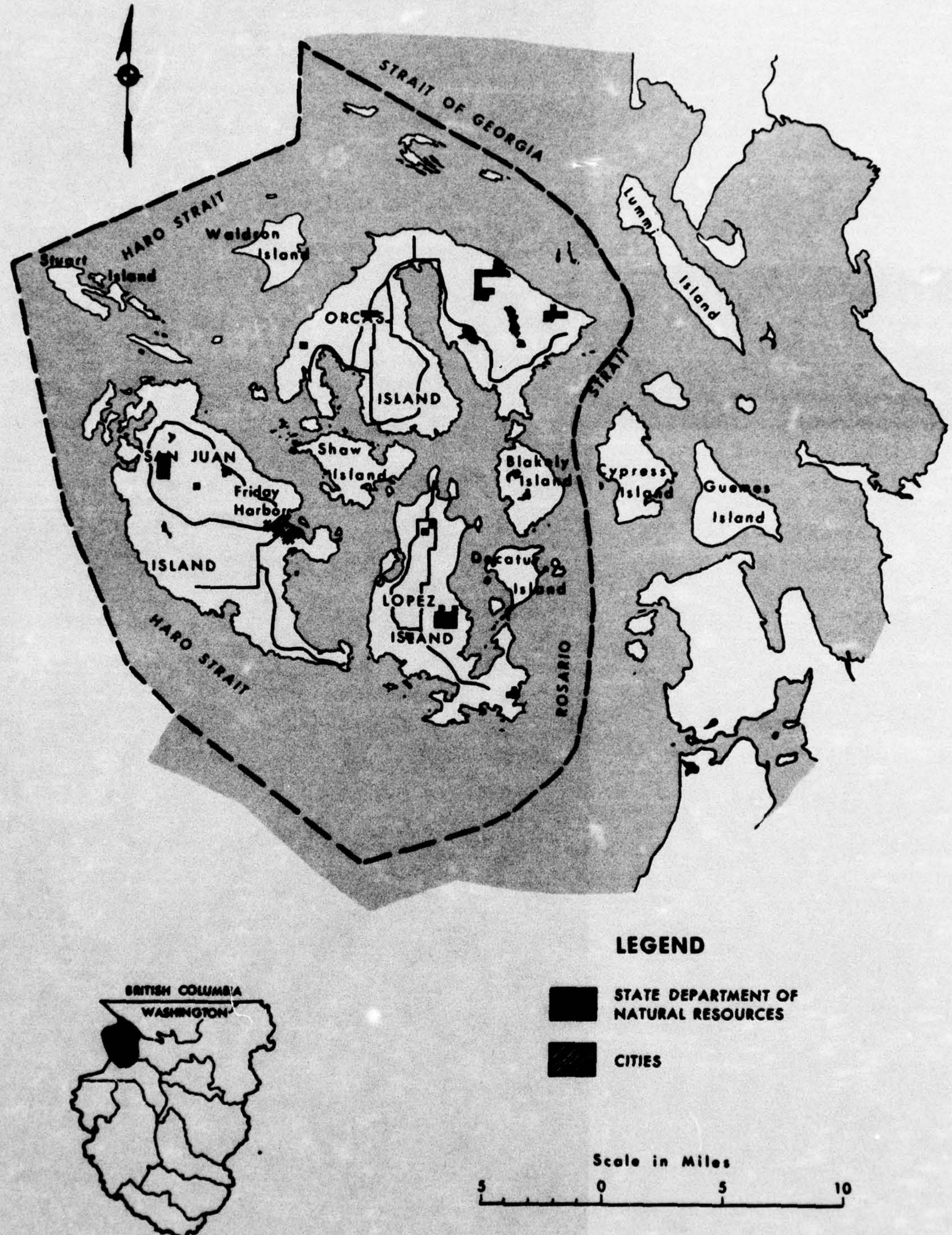
[a] Initial development.

[b] Does not include storage and distribution costs: See area Means to Satisfy Needs section.

[c] All figures are rounded.

San Juan Islands





SAN JUAN ISLANDS

Figure 12—1 Land Ownership

SAN JUAN ISLANDS

INTRODUCTION

The San Juan Islands (Figure 12-1), located between the southern end of Vancouver Island and the mainland of northwestern Washington, form an archipelago of 175 islands that vary in size from rocky islets and reefs, visible only at low tide, to areas in excess of 50 square miles. The three main islands, Orcas, San Juan, and Lopez, contain a major portion of the population and industry.

The islands have a stable permanent population, but also have a steadily growing transient population during the summer months. The water supply, although presently adequate, is limited, and may become an acute problem with the growth of summer population.

GEOGRAPHY

The island group was formed by partial submergence of a range of mountains extending as a spur of the Cascades from the mainland to Vancouver Island. Orcas Island, the highest of the group, rises abruptly to a height of 2,409 feet, and has the most irregular shoreline of all the islands in the chain. San Juan, Lopez, and Shaw Islands are primarily rolling plateaus with local hills less than 500 feet above sea level. The outer islands are less than 100 feet in elevation.

CLIMATE

The islands enjoy a favorable year-long climate. Summers are dry and cool, with an average July temperature of 15.5°C (60°F). January temperatures average 3.9°C (39°F). Yearly precipitation is light, varying from 17 to 29 inches across the islands.

POPULATION

The resident population of the San Juans, estimated at about 2,600 persons in 1965, has not varied greatly since 1930. The most notable population characteristic of the islands is a seasonal summer increase in the number of persons visiting or living in vacation homes and at resorts each year. (See photo 12-1.) The 1965 summertime population was estimated to be 23,000, a tenfold increase. The permanent population is mostly farm or rural nonfarm, with only a small urban population. No town or city exceeds about 1,200 permanent residents (2,500 summer population). The largest and only incorporated town is Friday Harbor on San Juan Island. A number of smaller unincorporated towns are scattered throughout the larger islands, and at least one village on each island serves a few settlers as a port and supply center.

ECONOMY

The economy of the San Juans is tourist-oriented. The tourist dollar is rapidly becoming the backbone of the island economy, with permanent residents adding new services, resorts, and facilities. The services industry has grown more than 60 percent since 1950, and in 1960 accounted for more than 25 percent of the total number of persons employed. Services, trade, and construction industries together employ more than one-half of the labor force.

A substantial decline in manufacturing has occurred since 1950, especially in food manufacturing. Agriculture also has declined in importance. Many of the larger farms have been converted into golf courses, hunting preserves, recreation camps, and riding academies. Crop and rangeland have been reduced to 30,000 acres, of which 75 percent is cropland. The remaining one-fourth of the farmland is used predominately for grazing sheep and other livestock, mostly in the interior of the larger islands.

San Juan County has been classed as a depressed area by the Federal Government. This indicates that the small population centers lack sufficient resources to solve transportation, domestic water supply, pollution control, harbor development, fishery, and recreation problems that are being created by the great influx of persons using the islands for recreation.

LAND USE

Table 12-1 shows how the 113,000 acres of land and inland water in the San Juans are classified as to use.

PHOTO 12-1. Tourists and summertime residents engage in a number of recreational activities, including boating, and cause a significant seasonal increase in population.

TABLE 12-1. General land use.

Use	Acres
Forestland	72,000
Cropland	19,000
Rangeland	9,000
Other land (high,barren)	9,000
Urban buildup	3,000
Inland water	1,000
Total land and inland water	113,000

Source: Appendix III, Hydrology.

PRESENT STATUS

WATER USE

The total municipal and rural-individual water use for the San Juan Islands is approximately 0.60 mgd, of which about 75 percent is surface water taken from the various streams on the larger islands. Ground water, drawn from wells, provides about 0.16 mgd. Water use data for the islands are presented in Table 12-2.

Municipals

Municipal water use, presently amounting to 0.59 mgd, accounts for over 98 percent of the total water use on the islands. The town of Friday Harbor which uses an average 0.33 mgd, accounts for over 55 percent of the municipal water use. Friday Harbor is the major water purveyor on the islands and has a per capita water usage of 170 gpd. Several rural community systems use a total of 0.26 mgd and have a combined per capita water usage of 220 gpd.

Industrial

The primary industries of the area are fishing, seafood canning, agriculture, and tourism. Water-use data for these industries are not available.

TABLE 12-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd)			Ground water usage (mgd)		
		Average daily	Maximum monthly	Maximum daily	Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Friday Harbor	1,212	0.33	0.67	0.70	—	—	—
Other rural community systems	1,176	0.11	0.21	0.32	0.15	0.30	0.45
Subtotal	2,388	0.44	0.88	1.02	0.15	0.30	0.45
RURAL-INDIVIDUAL USE	212	—	—	—	0.01	0.02	0.03
Total	2,600[b]	0.44	0.88	1.02	0.16	0.32	0.48
Summer population	23,000	—	2.59[a]	3.45	—	0.86[a]	1.15

[a] Based on assumed 150 gpcd and estimated 75 percent served by surface sources.

[b] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

Rural-Individual

About 200 persons living in rural areas use an estimated total of 0.01 mgd.

WATER SUPPLIES

There are relatively few water supplies on the islands. The municipal system of Friday Harbor, in serving an estimated resident population of 784 people, is the major public water supply on the San Juans. The town obtains its surface supply from Troutlake and provides disinfection prior to distribution. The capacity of the system is estimated to be 0.86 mgd. Accurate data on the total water available are not available for the islands, but it is evident that a lack of sufficient fresh water will become an acute problem with further residential development and expected increases in the summer tourist population.

WATER RIGHTS

The San Juan Islands have a total of 92 recorded water rights; of these, 39 are surface and 53 are ground (1966-1967).

Surface water under prime right permits and certificates total 6 mgd. In addition to this, 1 or 2 mgd are claimed under vester-rights. Applications on file indicate an additional 1 mgd is soon to be developed.

Irrigation accounts for half the surface water used - 3 mgd. Domestic supplies - 1.2 mgd; and stock water - 1.2 mgd, are also significant use catagories.

TABLE 12-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	—	1.3	—
Ground water	—	1.6	0.3
Total[a]	—	2.9	0.3

[a]About 5.2 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

Since most of the streams in this area are intermittent, a relatively intense farm pond program has evolved to provide summer storage of up to 1,017 acre feet (331 mg) under reservoir rights.

The unnamed outlet stream from Sportsman's Lake is the only stream in the basin that has been closed to consumptive appropriation.

Ground water rights in the basin total 1.7 mgd, with an additional 0.3 mgd pending in application form.

In this area rights for single and multiple domestic supplies are most significant and permit total withdrawals up to 1.6 mgd. Irrigation, stock and industrial developments account for withdrawal rates of 0.4 mgd, 0.3 mgd and 0.3 mgd, respectively. The average existing ground water development in this area yields less than 0.02 mgd. Table 12-3 shows water rights and applications in the San Juan Islands.

WATER RESOURCES

Fresh water resources for the islands consist of streams, lakes and reservoirs, and numerous low-yield wells. The quality of the available water is good, but the quantity, on both large and small islands (photo 12-2), is strictly limited, with no significant new sources in evidence.

SURFACE WATER

Quantity Available

Streams. Only a few streams flow on the San Juan Islands. Most of these flow intermittently, although some of the larger islands support well-defined perennial stream systems.

Precipitation data indicate that the average annual rainfall varies from 17 to 29 inches across the islands, increasing from south to north. Though adequate and continuous stream flow data are lacking, the average annual runoff is estimated to range from 5 inches in the southerly portion of the islands to 15 inches in the north.

Dams, Impoundments, and Lakes. The small lakes and reservoirs on the islands comprise about 1.4 square miles; reservoirs that provide municipal and irrigation water contain about 1,600 acre-feet of storage. Low runoff volumes and lack of natural holding basins preclude the likelihood of future significant storage projects.

On the matter of catchment of surface waters on small impoundments the County Soil Conservation Department estimates that there are over 300 such ponds existing within the islands. The minimum size of these ponds is 1/3 of a surface acre, although a

PHOTO 12-2. **Islands from the smaller, such as Sheep Island, to the larger, such as Orcas (foreground), experience scarcity or absence of fresh water.**

few are somewhat smaller. At least 2/3 of these are filled throughout the year, and no dug pond has failed to fill. They are used for all varieties of water supply, from bird sanctuaries to human consumption.

Quality

The quality of surface water from low-flow streams is similar to the ground water in storage, except during periods of significant surface runoff, because low-flow streams are sustained in part by contributions from ground water storage. Sewage disposal may impair the sanitary quality of lakes and streams somewhat in localized areas.

Physical. No data are available.

Chemical. No data are available.

Bacteriological. No data are available.

GROUND WATER

Quantity Available

Coarse Quaternary sediments provide better aquifers. Yields of wells completed in such aquifers rarely exceed 20 gpm; the largest recorded yield is 50 gpm. Some wells are drilled as deep as 500 feet into the older consolidated rocks to obtain sufficient water. These wells generally do not yield more than 10 gpm each.

Quality

Ground water data are limited. Based on information available, the hardness of ground water ranges from medium to hard in wells up to 132 feet in depth. One well of 168 feet in depth had a hardness of 8 mg/l, which is extremely soft. Table 12-4 gives available data on ground water quality.

TABLE 12-4. Ground water quality.

Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Calcium (Ca) (mg/l)	Magnesium (Mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Nitrate (NO_3) (mg/l)	Orthophosphate (PO_4) (mg/l)	Dissolved solids (mg/l)	Hardness ($CaCO_3$) (mg/l)	Specific conductance (μmho)[c]	pH
William Hughes	36/2W-14H	5/17/60	50	31	0.27	60.0	29.0	29.0	6.0	0.8	0.22	346	268	616	7.5
Roche Harbor Lime and Cement Co.	36/3W-17E	3/9/61		30	1.20	21.0	15.0	16.0	2.4	0.3	0.14	189	113	300	7.1
East Sound Water District	37/2W-13B	5/17/60	51	23	0.05	46.0	6.8	9.3	0.7	2.4	0.03	204	143	331	7.1
R. C. Purdue	37/2W-14A2	10/28/54	50	11	0.03	3.2	0.0	91.0	0.6	0.0	0.0	238	8	393	8.6
Vernon Curtis	37/2W-14C4	5/17/60	50	35	2.20[d]	66.0	27.0	39.0	2.7	0.1	0.03	413	274	676	7.8

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

The principal factor that determines present and future needs for water in the San Juan Islands is the seasonal summer population. Major water-using industries will decline in importance and use, with mineral aggregate production and seafood processing as declining and seasonal water users after 1980.

PROJECTED POPULATION GROWTH

Figure 12-2 shows estimated population for 1965 and projections of population through the year 2020. As shown, the 1965 permanent population (2,600) is expected to increase by about 8 percent to 2,800 by 1980, by 42 percent to 3,700 by the year 2000, and by 97 percent to 5,100 by 2020. Most of the expected increase will occur in and around the urban Friday Harbor area and on Orcas Island. The increase reflects the added services needed to support expanding tourism.

Table 12-5 through 12-7 also show the projected summertime population on the islands through the year 2020. The estimated 1965 summer population of 23,000 (as presented on Table 12-2) is expected to increase about 56 percent to 36,000 by 1980, 256 percent to 59,000 by 2000, and 454 percent to 106,000 persons by the year 2020.

PROJECTED INDUSTRIAL GROWTH

Production growth is not expected in major water-using industries in the basin. Rather, as shown in figure 12-3, a decline is projected. The lumber and wood products industries will reach almost nil by 1980, and food processing will follow the same pattern from 1980 to 2000.

Notwithstanding the industrial decline, the basin is expected to experience considerable economic growth. Most of this growth will result from recreational appeal of the islands. The abundance of land and salt water recreation sites will draw increasing numbers of recreationists to the Basin. This, combined with an increase in the number of persons who maintain summer residences on the islands, will increase per capita income and economic activity.

PROJECTED WATER REQUIREMENTS

Total annual average water requirements in the basin are expected to reach 1.1 mgd by the year 2020, a 205-percent increase over present requirements. Surface water sources will supply 80 percent of the projected water needs. Tables 12-5, 12-6, and 12-7 itemize projected water use in 1980, 2000, and 2020, respectively. Table 12-8 summarizes water use from the present through 2020.

Municipal

Annual average municipal water requirements are projected to reach 0.50 mgd by 1980, 0.73 mgd by 2000, and 1.12 mgd by 2020. Most of the demand will be supplied from the Friday Harbor and Orcas Island surface sources. Per capita water consumption, which totaled 185 gpd in 1965, will decline to 142 gpd by 1980, then rise to 158 gpd by 2000, and again reach 185 gpd by 2020. It is assumed that installation of additional meters and increased water rates to meet system expansion and improvements will account for the drop in per capita water use between 1965 and 1980. The Friday Harbor water system will supply most of the municipal water used.

Industrial

Industrial water needs were relatively minor in 1965 and are expected to decline to an insignificant amount by the year 2020.

Rural-Individual

Rural-individual needs are projected to be less than 1 percent of the total basin needs. Present sources are barely adequate, and additional ground water development to supply needs does not appear possible.

Municipal Nonresident

Summertime water needs will create the greatest demands on many systems in the basin because of a large projected seasonal increase in population that coincides with the period of least precipitation. Needs during summer, presently 3.5 mgd, are expected to average 16.0 mgd by 2020 during the maximum month - a 460 percent increase over present requirements.

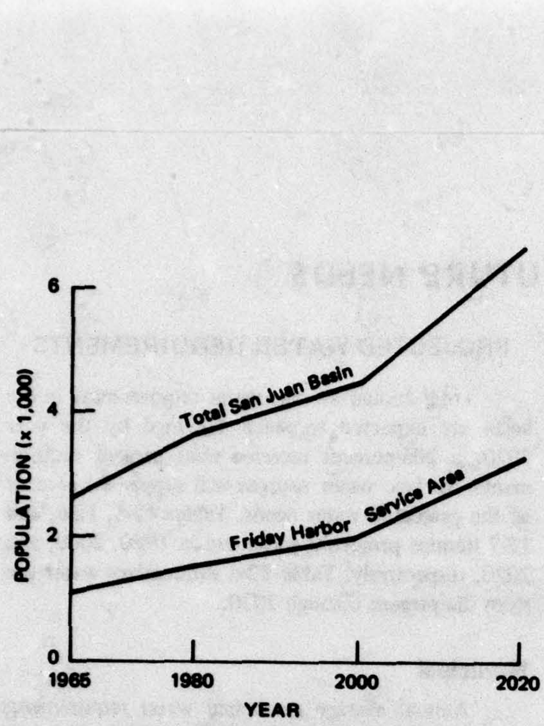


FIGURE 12-2. Projected population growth.

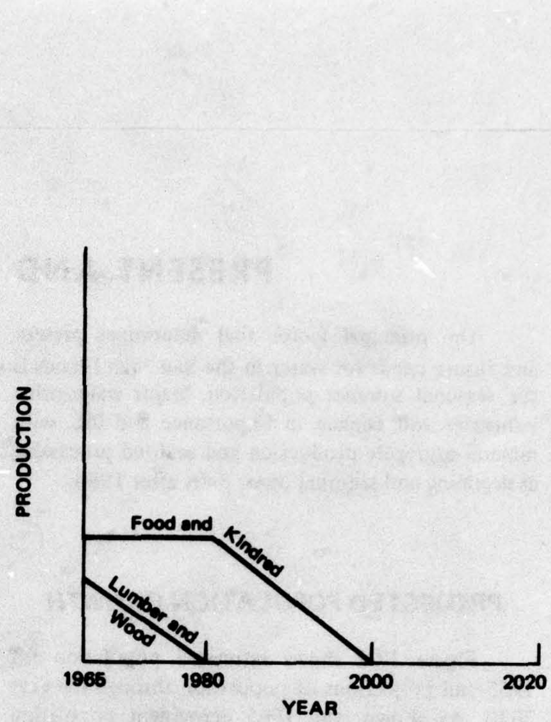


FIGURE 12-3. Relative production growth for major water-using industries.

TABLE 12-5. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Friday Harbor	1,400	0.27	0.38	—	—
Other rural communities[a]	1,200	0.10	0.14	0.13	0.18
Subtotal	2,600	0.37	0.52	0.13	0.18
RURAL-INDIVIDUAL USE[b]	200	—	—	0.02	0.025
INDUSTRIAL USE					
Food and kindred[d]	—	—	—	—	—
Total[e]	2,800	0.40	0.50	0.20	0.20
Summer population use[c]	36,000	—	4.00	—	1.40

[a]The breakdown between surface and ground sources is based on 1965 conditions.

[b]No surface use projected for rural individual.

[c]Summer population projected utilizing growth factors obtained from the Recreation Committee projections of effective populations for the basins. Water use based on 150 gpcd and estimated 75% served by surface sources. It should be noted, however, that the source of water as to surface or ground may not be as projected. Desalination is a possibility.

[d]Very small quantity of water projected.

[e]Figures are rounded.

TABLE 12-6. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Friday Harbor	2,000	0.42	0.60	—	—
Other rural communities[a]	1,480	0.13	0.18	0.18	0.25
Subtotal	3,480	0.55	0.78	0.18	0.25
RURAL-INDIVIDUAL USE[b]	220	—	—	0.02	0.03
INDUSTRIAL USE					
Food and kindred[d]	—	—	—	—	—
Total[e]	3,700	0.60	0.80	0.20	0.30
Summer population use[c]	59,000	—	6.70	—	2.20

[a]The breakdown between surface and ground sources is based on 1965 conditions.

[b]No surface use projected for rural individual.

[c]Summer population projected utilizing growth factors obtained from the Recreation Committee projections of effective populations for the basins. Water use based on 150 gpcd and estimated 75% served by surface sources. It should be noted, however, that the source of water as to surface or ground may not be as projected. Desalination is a possibility.

[d]Very small quantity of water projected.

[e]Figures are rounded.

TABLE 12-7. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Friday Harbor	3,250	0.75	1.10	—	—
Other rural communities[a]	1,600	0.15	0.20	0.22	0.31
Subtotal	4,850	0.90	1.30	0.22	0.31
RURAL-INDIVIDUAL USE[b]	250	—	—	0.03	0.04
INDUSTRIAL USE					
Food and kindred[d]	—	—	—	—	—
Total[e]	5,100	0.90	1.30	0.30	0.40
Summer population Use[c]	106,000	—	12.00	—	4.00

[a]The breakdown between surface and ground sources is based on 1965 conditions.

[b]No surface use projected for rural individual.

[c]Summer population projected utilizing growth factors obtained from the Recreation Committee projections of effective populations for the basins. Water use based on 150 gpcd and estimated 75% served by surface sources. It should be noted, however, that the source of water as to surface or ground may not be as projected. Desalination is a possibility.

[d]Very small quantity of water projected.

[e]Figures are rounded.

TABLE 12-8. Summary of projected water needs.

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	2,388	0.4	0.9	0.2	0.3	0.6	1.2
	1980	2,600	0.4	0.5	0.1	0.2	0.5	0.7
	2000	3,480	0.6	0.8	0.2	0.3	0.8	1.1
	2020	4,850	0.9	1.3	0.2	0.3	1.1	1.6
Rural Individual	1965	212	—	—	0.0	0.0	0.0	0.0
	1980	200	—	—	0.0	0.0	0.0	0.0
	2000	220	—	—	0.0	0.0	0.0	0.0
	2020	250	—	—	0.0	0.0	0.0	0.0
Totals	1965	2,600[a]	0.4	0.9	0.2	0.3	0.6	1.2
	1980	2,800[a]	0.4	0.5	0.1	0.2	0.5	0.7
	2000	3,700[a]	0.6	0.8	0.2	0.3	0.8	1.1
	2020	5,100[a]	0.9	1.3	0.2	0.3	1.1	1.6
Summer Population	1965	23,000	—	2.6	—	0.9	—	3.5
	1980	36,000	—	4.0	—	1.4	—	5.4
	2000	59,000	—	6.7	—	2.2	—	8.9
	2020	106,000	—	12.0	—	4.0	—	16.0

Note: All usage figures are rounded to one decimal place.

[a] Does not include summer population.

MEANS TO SATISFY NEEDS

Based on projections of population and water-oriented recreation activities, substantial growth is expected for the San Juan Islands in the years ahead. To adequately provide for this future expansion, water supply planning is urgently needed.

The San Juan Islands receive relatively little precipitation and produce small runoff volumes or ground-water recharge. The economic potential here can be realized only by overcoming the expected water supply deficiencies.

Accurate data on the total amount of water that is available for development does not exist for this area, but it is evident that a lack of sufficient fresh water will become an acute problem with further residential development and expected increases in summer population.

With maximum month water demand projections for the year 2020 standing at nearly 70 mgd (includes the summer population water use) and a present water usage of about 4.7 mgd during the maximum month, it may be seen that there is considerable room for water supply shortages to develop. While accurate data on the dependable yields and capacities of the systems located on the islands are not readily available for comparison, it is felt that at the present time many supplies are near their capacities during this period. Noticeable drops in the water table have occurred in some areas and instances of saltwater intrusion to some wells have been reported. Indications are that limited water is available for further development.

The water supply for the town of Friday Harbor is estimated to have a capacity of 0.86 mgd. With maximum monthly usage presently nearing 0.7 mgd, this system—the major water purveyor on the islands—is approaching its capacity. Table 12-9 shows present and future water needs.

WATER RECLAMATION

A possible avenue of approach to solution of future water shortages in this area is desalination. Although this would be a relatively expensive source, future justification may be forthcoming in the light of future projections and other available water sources. Numerous desalting plants are now in operation in the United States. Key West, Florida; Buckeye, Arizona; Coalinga, California; and Roswell, New Mexico are cities which rely wholly or in part on desalination facilities.

Costs associated with desalination are decreasing with improved technology, but in most instances use of desalination facilities are economically feasible only in situations where the nearest potable water supply is a considerable distance away. This is the case in the San Juan Islands which are surrounded by marine waters, but detailed analyses would be required to determine if this solution is a favorable one when compared with other possible alternatives.

The Key West Desalting Plant (2.62 mgd) might be used for determination of cost estimates. This plant utilizes the multistage flash evaporation process to deliver desalted water at approximately 85 cents per 1,000 gallons with fuel oil as the source of energy. The U.S. Atomic Energy Commission predicts costs as low as 19 cents per 1,000 gallons for the integrated nuclear power desalting plants by 1980, but costs of this order will be realized only in extremely large plants producing 500 to 800 mgd.

It is estimated that a water desalination plant of sufficient size to provide 10 mgd would cost about $13,500,000 based on studies made for the Key West area. In the San Juans, construction of a plant of this size would assume that the future needs of 10 to 13 mgd would occur primarily in one area which does not appear to be very realistic. While most of the demands may be generated in the Friday Harbor area, other areas will also become important for water supply. A possibility here would be the installation of smaller size desalination units which would provide for more localized areas of population and recreation concentrations. The cost of construction of a 2.4 mgd plant was determined to be about $3,560,000 in the Key West studies.

WATER TRANSPORT

In addition to desalination, an alternative for additional water supply would be barging of water from the mainland to storage areas on the islands. This alternative, however, does not appear to be

economically feasible based on a transportation need of 10 mgd. This would involve barging nearly 50,000 cubic yards or about 42,000 tons of fresh water daily to the islands.

LAND TREATMENT FOR RAINFALL RECOVERY

The use of catch basins or catchment areas to gather water for storage may be a possibility. The San Juans do not receive an excess of rainfall, but basins might be used on a local basis. Detailed studies would be required to determine the feasibility of this alternative and a way of integrating separate areas for maximum yield to, as an example, a water treatment plant.

A critical water supply situation appears to be developing in the San Juan Islands. Water supply studies keyed to the solution of impending water shortages are urgently needed and should be initiated at the earliest possible date.

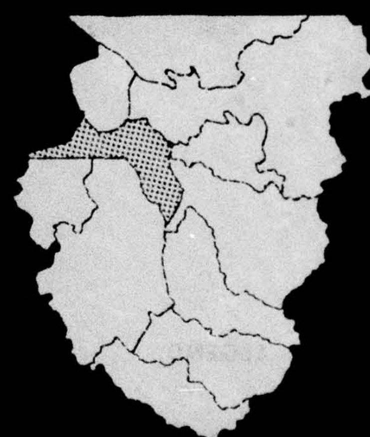
TABLE 12-9. M & I Water Supply Capital Improvements in the San Juan Islands

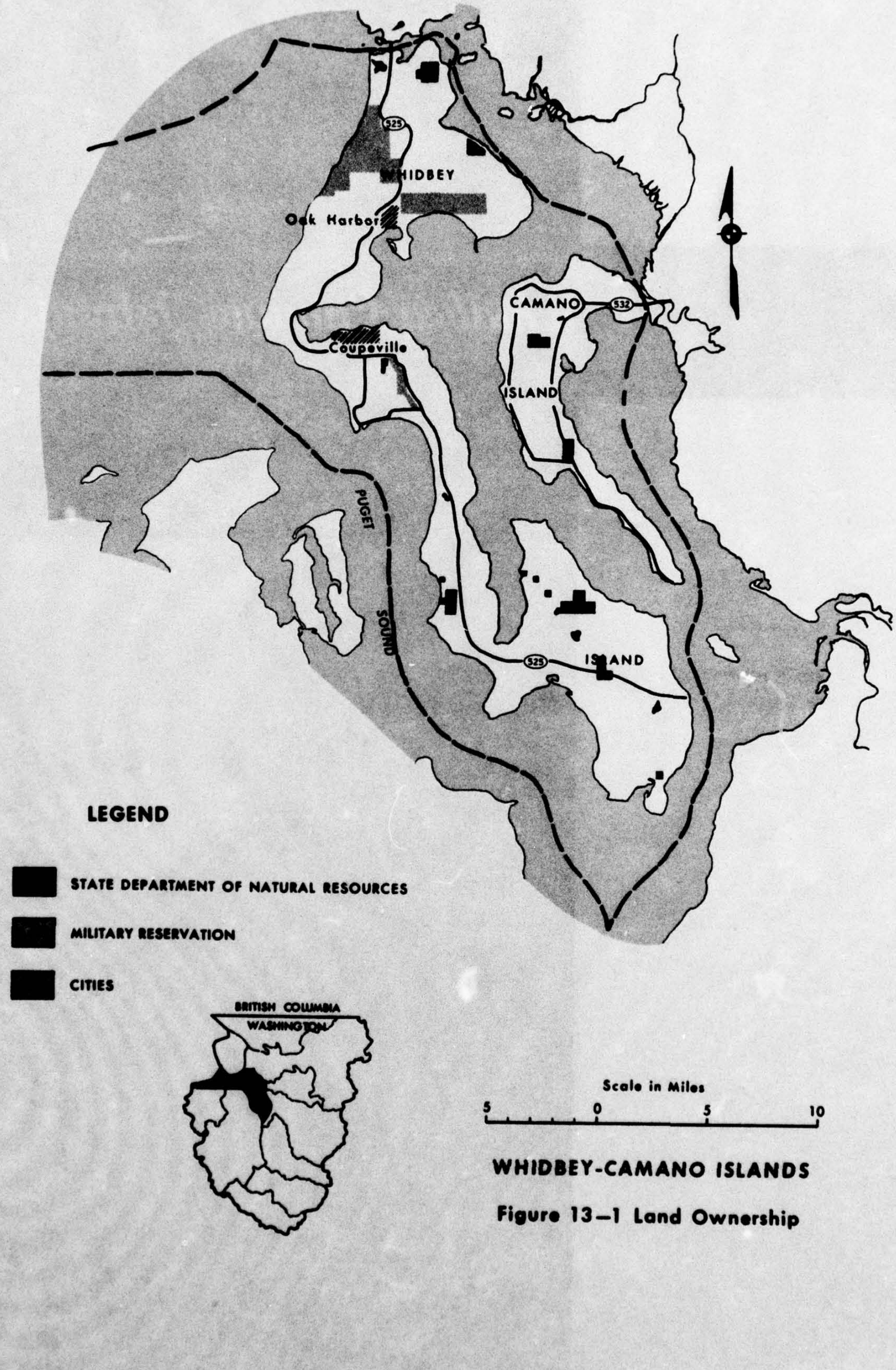
	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	1,212	1,400	2,000	3,260
FRIDAY HARBOR				
Optimum	0.8	0.9	1.3	2.1
Capital Improvements	0.1	0.1	0.4	0.8
Population Served	1,176	1,200	1,480	1,600
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	0.8	0.8	10	11
Capital Improvements	0.3	—	0.2	0.1
Population Served	23,000	36,000	59,000	106,000
SUMMER TOTAL POPULATION				
Optimum	15.1	23.7	38.8	69.7
Capital Improvements	12.5	8.6	15.1	30.9
Population Served	2,388			
TOTAL[1]				
Capital Improvements	0.4	0.1	0.6	0.9

NOTE: Figures are rounded.

[1] Does not include summer population.

Whidbey-Camano Islands





WHIDBEY-CAMANO ISLANDS

Figure 13—1 Land Ownership

WHIDBEY-CAMANO ISLANDS

INTRODUCTION

Whidbey-Camano Islands, Figure 13-1, are located in the north end of Puget Sound, just west of the Skagit and Stillaguamish River deltas.

The fresh water supply for the islands (almost entirely ground water), although reasonably adequate for present needs, is considered not capable of development to meet the expanding needs of any significant population and industrial growth. Therefore, accurate, complete data are required to permit intelligent planning of new water supplies in the immediate future.

GEOGRAPHY

Whidbey and Camano Islands comprise a total land area of 210 square miles and have a generally low, flat terrain, with maximum elevation less than 600 feet above sea level. Whidbey Island, the larger of the two, is a narrow island about 40 miles long, lying in a north-south direction from northern Puget Sound to the Rosario Strait east of the San Juan Islands. It is separated from the mainland by deep salt water channels 2 or more miles wide, except at the northern end, where the channel narrows to 1,300 feet at Deception Pass. The island is generally flat and rolling, with elevations less than 500 feet, and has a land area of 168 square miles. The shoreline is relatively steep, and falls away sharply to narrow beaches.

Camano Island, 16 miles long with an area of 38 square miles, also lies in a north-south direction, and is about evenly spaced between central Whidbey Island and the mainland. It is low and level, except at the northern end, where it rises to 580 feet above sea level.

Both islands are connected to the mainland by bridges at their northern ends. In addition, Whidbey Island is served by ferry connections from Port Townsend to its central portion at Keystone and from Mukilteo near Everett on the mainland to Clinton near the southern end of the island.

CLIMATE

The climate of the islands is generally mild and uniform because of the small range of elevations, the rain shadow effect of the Olympic Mountains, and the tempering effect of the surrounding waters. Mean annual precipitation is about 22 inches; 15 percent falls during the summer months of June through August, and 65 percent falls during October through March. Average annual precipitation ranges from 17.73, measured at the U.S. Weather Bureau station in Coupeville on the western portion of Whidbey Island, to 25 inches in the southern part of the island and on Camano Island.

POPULATION

The population of the islands, 20,200 in 1965, has shown a rapid growth from about 11,000 in 1950 to 19,638 in 1960. This 110-percent increase for the 15-year period compares with a statewide increase of about 20 percent. Most of the increase has resulted from the establishment of military bases near Oak Harbor and Crescent Harbor. Greater population growth would probably have occurred if better access were available to metropolitan Seattle.

ECONOMY

Economic conditions on the islands, as reflected by employment, are good. Employment in agriculture, forestry, and fishing has decreased since 1950, but all other industries have increased their number of employees, so that the total number of persons employed in 1960 exceeded 3,870. This figure excludes Federal employees at military installations, which contribute substantially to the economic health of the islands.

LAND USE

About 63% (85,000 acres) of the land in the Whidbey-Camano Islands is considered forest land, consisting of forest or brush which has replaced the

native forest. In land use, cropland, or farming areas, ranks second consuming 23,000 acres, (19% of the total area).

Due to the area's recreation potential for summer and retirement homes and the excellent growing season, cropland and urban buildup areas are expected to increase in acreage in the future.

TABLE 13-1. General land use.

Type	Acres
Forestland	85,000
Cropland	23,000
Rangeland	2,000
Other land	12,000
Urban buildup	11,000
Inland water	1,000
Total land and inland water	134,000

Source: Appendix III, Hydrology.

PRESENT STATUS

Presently available fresh water supplies, almost exclusively ground water, are at best marginally capable of satisfying existing municipal and industrial demand. The supply problem can be expected to become acute with significant growth in population and industry.

WATER USE

Water use on Whidbey and Camano Islands presently averages about 2.32 mgd. This reflects only municipal and rural-individual use. Industry is not a significant water user in the basin, however, so the figure of 2.66 mgd provides a fairly accurate index of total use. Municipal consumers, including Whidbey Island Naval Air Station, use about 77 percent of the total water used in the Islands. Table 13-2 shows a breakdown of water use on the islands.

Municipal

About 16,185 municipal consumers on Whidbey and Camano Islands use an average of 2.1 mgd, an overall per capita use rate of 123 mgd. About

TABLE 13-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Maximum daily	Ground water usage (mgd) Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Oak Harbor	4,540	—	—	—	0.35	0.70	1.10
Naval Air Station	4,800	1.00	1.40	2.00	—	—	—
Coupeville	1,200	—	—	—	0.12	0.24	0.30
Langley	455	—	—	—	0.15	0.30	0.43
Clinton	420	—	—	—	0.03	0.06	0.08
Rural community systems	4,770	—	—	—	0.45	0.89	1.38
Subtotal	16,18[c]	1.00	1.40	2.00	1.10	2.19	3.29
RURAL-INDIVIDUAL USE	4,015	—	—	—	0.22[a]	0.44	0.66
INDUSTRIAL USE							
Naval Air Station[b]		1.50	1.75	2.00	—	—	—
Total	20,200	2.50	3.15	4.00	1.32	2.63	3.95

[a] Based upon 55 gpcd.

[b] Supplied by Anacortes.

[c] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

7,600 municipal consumers in Oak Harbor, Langley, and Coupeville, the three largest Whidbey Island communities, use an average of 0.59 mgd, a per capita use of 77 gpd. Table 13-3 shows water use in these three communities.

Nearly 1,900 municipal users on Camano Island use an average of 0.22 mgd, a per capita use of 117 gpd. The 4,800 municipal consumers at Whidbey Island Naval Air Station use an average of 1.0 mgd, about 38 percent of total basin use and a per capita use of 208 gpd. The per capita use in the island communities is substantially lower than the municipal per capita use for other basins or for the Naval Air Station, reflecting the rural nature of the area and the existence of substandard water supplies.

TABLE 13-3. Water use in major island cities.

	Oak Harbor	Langley	Coupeville
Population served	5,100.00	1,250.00[a]	1,290.00
Total connections	1,388.00	346.00	430.00
Water requirements			
Annually (mg)	128.00	49.40	37.00
Average daily (mgd)	0.35	0.14	0.12
Peak daily (mgd)	1.10	0.25	0.20
Per capita use (gpd)	68.00	112.00	78.00

[a]About 60 customers on Sandy Point and vicinity are seasonal.

Industrial

Present industrial demands for fresh water are small, and are supplied on an individual basis by the various small industries. No specific data on industrial use are presently available.

Rural-Individual

An estimated 4,015 persons in rural areas (photo 13-1), not served by municipal water systems, use a daily average of 0.22 mgd and a maximum monthly usage of 0.44 mgd. This reflects an average per capita use of less than 55 gpd.

WATER SUPPLIES

Ground water is the source of supply for all water systems on the islands, with one exception. The Naval Air Station at Ault Field is supplied by the city of Anacortes, which utilizes the Skagit River as its source of supply. This system is described in the Skagit-Samish Basin report.

PHOTO 13-1. Rural-individual use, supplied from ground water sources, accounts for about 20 percent of all water used in the basin.

Municipal

The municipal water systems of Oak Harbor, Langley, and Coupeville supply 6,195 of the 16,185 people served by public systems on the islands.

Coupeville, the county seat of Island County, lies on the south shore of Penn Cove in central Whidbey Island. The town doubled in size between 1950 and 1960, primarily as a result of the buildup of the U.S. Naval Air Station near Oak Harbor.

The Coupeville water system serves a greater area than any other system in Island County. Historically, this is the result of a decision years ago to seek customers outside the city limits to support the system, and the purchase of the Fort Casey infiltration galleries to supplement the town's water source. Coupeville also sells water to a number of summer homes several miles west of the city limits, although the city does not own the distribution mains beyond its incorporated limits.

Data on Coupeville's water supply are listed in Table 13-4.

Well No. 1 was the victim of sea-water infiltration several years ago, but, following several years of inactivity, it was returned to service with a smaller pump. The water is extremely hard, and extensive pumping will cause further deterioration in its quality, making it unacceptable. The town relies primarily on the softer water from the Fort Casey infiltration galleries as a source of supply, although these galleries are drawn nearly dry during periods of peak water demand. Well No. 2 yields hard water, and is presently being used on a standby basis only, because it has been pumping sand recently. Extensive

TABLE 13-4. Coupeville water supply.

Source	Yield	
Well No. 1	140 gpm	(0.20 mgd)
Well No. 2 (standby)	165 gpm	(0.24 mgd)
Infiltration galleries	165 gpm	(0.18 mgd)
Total safe yield	470 gpm	(0.62 mgd)

renovation will be necessary to restore this well to satisfactory everyday use.

Lack of a good and adequate water supply is a significant factor in development in the Coupeville area. The U.S. Geological Survey, in its ground-water survey of Island County, concludes that the water table in the Coupeville area is hydraulically connected with Puget Sound, and that there is no substantial quantity of potable groundwater available in the area.

Langley is the smallest of Island County's incorporated cities and the only one located on the south end of Whidbey Island. Its population has remained fairly constant; its presently estimated population of 472 is slightly less than the 1940 high of 505.

The existing water system in Langley serves not only the incorporated city but also areas to the west and east of the town. In addition, it serves the South Whidbey consolidated schools, which, with an enrollment of approximately 800, constitute a major customer.

The Langley system relies on three wells as its source of supply, as listed in Table 13-5. The city has not experienced water shortage, even though the existing storage capacity is less than one-fourth the peak daily demand. It is apparent from Tables 13-3 and 13-5, that, with care, Langely has an adequate water supply to meet its own needs and those of its outlying areas for the immediate future. Further, it is expected that the city can develop its present aquifers for additional future supplies.

TABLE 13-5. Langley water supply.

Source	Yield	
Well No. 1	90 gpm	(0.13 mgd)
Well No. 2	100 gpm	(0.15 mgd)
Well No. 3	200 gpm	(0.29 mgd)
Total	390 gpm	(0.57 mgd)

Oak Harbor is situated on North Whidbey, adjoining the Whidbey Island Naval Air Station. It was a small community of 350 in 1940 with a history of slow growth, but with the establishment of the Naval Air Station nearby, its population mushroomed to a 1967 figure of 5,100, making it the largest city in the county.

Oak Harbor obtains its water supply from seven wells with a combined pumping capacity, as shown in Table 13-6, adequate to meet present peak water demands. To date, the city has not experienced any water shortage because present policy restricts water service to the city proper, so that the many trailer courts and developments on the fringes of the city must rely on their own individual water supplies.

However, the need for an additional source of water is urgent. It is evident from the data in Tables 13-5 and 13-8 and population projections that Oak Harbor will not be able to meet estimated peak water demands after 1975. The Naval Air Station also urgently needs water, and, unless agreement is reached soon between the Navy and the City, will proceed unilaterally to construct a water pipeline to meet its own requirements.

Clinton. Clinton, for the last several years, has been exploring ways of upgrading its supplies to improve the quantity and quality of its wells.

Industrial

There are no sizeable individual industrial water supplies on the islands.

Rural-Individual

About 1,900 individual water systems supply an estimated 4,015 persons. All of these systems obtain their supplies of water from ground sources.

TABLE 13-6. Oak Harbor water supply.

Source	Yield	
Well No. 3	75 gpm	(0.11 mgd)
Well No. 5	300 gpm	(0.43 mgd)
Well No. 6	500 gpm	(0.72 mgd)
Well No. 7	100 gpm	(0.14 mgd)
Well No. 8	210 gpm	(0.30 mgd)
Well No. 9	200 gpm	(0.29 mgd)
Well No. 10	160 gpm	(0.23 mgd)
Total	1,545 gpm	(2.22 mgd)

WATER RIGHTS

There are 247 recorded water rights in the Whidbey-Camano Islands; of these, 97 are surface and 150 are ground (1966-1967). Recorded prime water rights for the Whidbey-Camano Island area indicate a total allowable rate of diversion of 7 mgd, 5 mgd being used for irrigation purposes. In addition 0.1 mgd has been appropriated under supplemental rights.

In total, 147 acre feet (50 mg) per year has been appropriated under three reservoir storage rights.

Consumptive appropriation closures have not been imposed on any streams in this area, however, one diversion on a small stream is subject to a low-flow restriction.

As of September 30, 1966, a total quantity of 20 mgd had been appropriated under prime ground water right permits and certificates in the Whidbey-Camano Islands. No supplemental instantaneous rates of withdrawals have been granted under rights in this area. Ground water applications on file indicated six developments were under consideration to withdraw additional quantities at rates totaling 0.6 mgd.

TABLE 13-7. Consumptive water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	---	1.8	---
Ground water	1.3	14.0	1.5
Total[a]	1.3	15.8	1.5

[a]About 9 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

Under prime rights 14 mgd or about 70 percent of the total appropriated quantity can be applied to individual and community domestic supplies. Quantitatively irrigation use ranks second in importance with a total appropriation of 7 mgd.

A few wells have been developed by community water companies with production rates as high as 0.7 mgd, however, the majority of the wells produce less than 0.14 mgd. The average capacity of wells in this basin is about 0.12 mgd. Table 13-7 shows water rights and applications in the Whidbey-Camano Basin.

WATER RESOURCES

Quantities of both surface and ground water are limited in the islands, and are not sufficient to support more than minor increases in domestic and industrial demand.

SURFACE WATER

The only surface water on the islands consists of small streams, mostly intermittent, and several small lakes. Surface water is not used as a fresh water source, other than the role it plays in recharging the ground water supplies.

Quantity Available

Streams. Although there are no perennial streams in the northern portion of Whidbey Island, and only a few in other portions of either Whidbey or Camano Islands, there is some surface drainage to marine waters through several small, mostly intermittent, streams. There are also several small lakes on the islands with a combined area of about 747 acres.

Average annual runoff from the area has been estimated to be about 168,000 acre-feet, or 68 percent of the average annual precipitation. Of the 168,000 acre-feet, Whidbey Island discharges about 136,000 acre-feet and Camano about 32,000 acre-feet. The least annual runoff is expected to occur once in 50 years and has been estimated to be about 72,000 acre-feet.

Dams, Impoundments, and Lakes. There are a number of small lakes on the two islands, but most are smaller than 15 acres each. The three largest lakes on Whidbey Island are Cranberry Lake (128 acres), Lone Lake (92 acres), and Deer Lake (82 acres). These lakes generally are in equilibrium with the local ground water table.

While the above figures indicate that a substantial surface water potential exists for the islands, closer inspection reveals that, because of the flat nature of the terrain, tapping these supplies to a

significant extent would be extremely complex and costly.

Quality

Little information is currently available on the quality of surface water in the islands. Routine surface water quality measurements have not been made.

Quantity Available

The Whidbey-Camano Islands are characterized by extensive Quaternary deposits underlying the entire land surface. Much of these are till and outwash having low water content because of their fine compacted nature.

GROUND WATER

Ground water sources are recharged entirely by local precipitation and are thus limited. Quality varies substantially, but in general is inferior to that of other basins in the Puget Sound Area.

Below the till bodies, however are found many aquifers of significance. Those above sea level are a limited source of ground water. Those aquifers found below sea level generally exhibit artesian conditions and are the principal source of water used on the islands.

Precipitation is the only source of recharge to the island aquifers. Although about 10,000 acre-feet of recharge is available to the aquifers above sea level, it is estimated that only about 60 to 70 percent of this is actually absorbed by them.

Quality

The quality of ground water in the islands is generally adequate for domestic uses, but is not of as good quality as ground water in other parts of the Puget Sound Area. The concentration of dissolved solids in ground waters of the islands usually ranges between 100 and 300 mg/l, with values above 300 mg/l in some places. Hardness values (calcium carbonate) are usually less than 120 mg/l on southern Whidbey Island and greater than 120 mg/l on the rest of Whidbey Island and Camano Island. The water in the Coupeville system is among the hardest in the county; samples from the wells tested by the Washington State Health Department yield hardness values of more than 800 mg/l, as measured in terms of calcium carbonate hardness.

Objectionable concentrations of iron have been reported in both shallow and deep wells in certain definite areas and some scattered locations on Whidbey Island. The Coupeville water is also high in iron content and releases a sulfide odor when the water is heated.

One well on Whidbey Island reportedly has been abandoned because, through excessive pumping, salt water has entered the contributing ground water supply. The Coupeville vicinity is particularly troubled with sea-water infiltration, as are numerous wells along some coastal areas.

Other factors besides the location of the well appear to affect the water quality. Rainfall may cause seasonal variations in the ground water, especially in locations where the aquifer lies near the land surface. Evidence is not conclusive, but there are indications that the quality of the ground water deteriorates progressively with depth below sea level, and an increase in the rate of ground water withdrawal generally results in an increase in the dissolved solids content of the water. As a result of increased use, the added drawdown of the water table results in an increasing percentage of harder water, presumably from greater depths.

PRESENT AND FUTURE NEEDS

Local supplies of water must come from ground sources because the Islands contain no perennial streams or lakes capable of furnishing enough water to meet the needs. Ground supplies depend on rainfall for replenishment, and this has proved inadequate in some cases. Populated areas have experienced water shortages or have had to rely on highly mineralized water.

Most of the land remains forest-covered. Agriculture has diminished in importance during the past several years. Population is concentrated along the shorelines of Camano and Whidbey Islands in platted subdivisions outside incorporated cities. Each subdivision has developed its own small system so that now 150 individual systems serve about 72 percent of both permanent residents and transient seasonal population. Lack of organized effort by the individual communities has resulted in a variety of water supply systems, many of which are substandard in quality, having overlapping service areas and unneces-

sary duplication of facilities. At the same time, certain areas that lack adequate ground water do not have access to existing ground water resources. Continuing population growth, coupled with increased per capita water requirements, narrows the surplus gap between supply and demand for fresh water. The increased per capita use is caused primarily by the increase in water consuming appliances, gardening, and fire protection requirements stipulated in mortgage loan contracts.

Individual water systems still serve many areas where population growth would make a community system feasible. The systems of Langley and Coupeville serve a considerable area outside their respective corporate limits. The U.S. Navy facilities are supplied from the Anacortes system.

Wells along the shoreline of Whidbey and Camano Islands, particularly near Coupeville, are troubled with sea water infiltration, a problem that becomes more acute with an increase in water drawn from the wells.

The northern part of Whidbey Island is populated primarily with permanent residents, whereas in southern Whidbey and Camano Islands, a transient seasonal and recreational population predominates.

Although some isolated areas are presently experiencing a fresh water shortage, with proper distribution and utilization, available ground water should be adequate to supply the demand until about the year 1985. The projected normal population growth (Figure 13-2) will increase the water requirements so that by 1985 out-of-basin water sources will be necessary.

The three adequate sources outside the Island are: the Anacortes municipal supply, the Skagit River, and the Stillaguamish River. The U.S. Navy is planning to construct a water transmission line from Anacortes to the Naval Air Station, and with proper planning, this could be developed as a cooperative project capable of supplying the water needs of the Naval Air Station as well as all of Whidbey Island as far south as Coupeville. The remainder of the island would be adequately supplied by ground sources until 1985, after which the line from Anacortes could be extended to serve the entire island. (See Figure 13.3). A separate single system serving all of Camano Island from the Stillaguamish River is feasible.

Ten local water districts, including the three existing municipal systems, could adequately handle the water needs of the whole of Whidbey Island, and would prevent the inefficient duplication and overlapping of the present individual systems. A single district would be most effective for Camano Island. These districts would make most efficient use of existing ground water supplies for the present, with provisions for connecting into the transmission system as future needs require.

Based on present supply and the projected growth, it is estimated that sources outside the Islands will supply 60 percent of the total water needs by 1985, 75 percent in the year 2000, and 90 percent in 2020.

Projected population growth and the corresponding water needs are shown in tables 13-8, 13-9, and 13-10 for the years 1980, 2000, and 2020, respectively. Future water needs are summarized in Table 13-11.

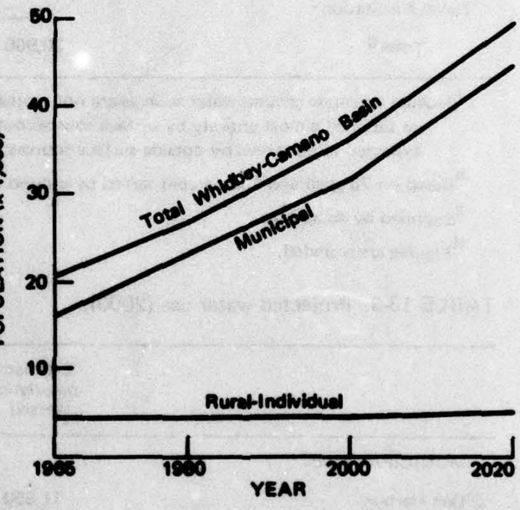


FIGURE 13-2. Projected population growth.

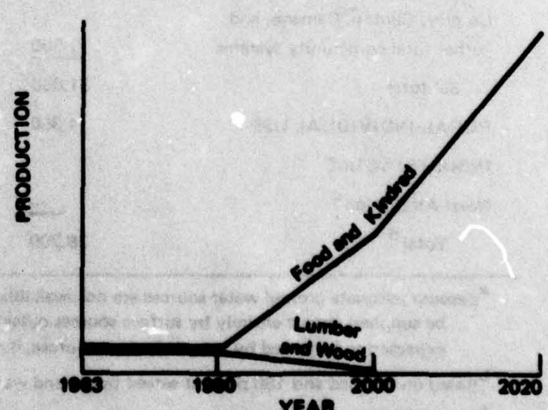


FIGURE 13-3. Relative production growth for major water-using industries.

TABLE 13-8. Projected water use (1980).

	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
MUNICIPAL USE[a]					
Oak Harbor	7,500	---	---	---	---
Naval Air Station	6,000	---	---	---	---
Coupeville	2,000	---	---	---	---
Langley, Clinton, Camano, and other rural community systems	7,400	---	---	---	---
Subtotal	22,900	2.6	3.6	1.8	2.5
RURAL-INDIVIDUAL USE	4,000	---	---	0.3[b]	0.4
INDUSTRIAL USE					
Naval Air Station[c]	---	2.0	2.5	---	---
Total[d]	26,900	4.6	6.1	2.1	2.9

[a] Because adequate ground water sources are not available on the islands, it is expected that future growth will be supplied almost entirely by surface sources outside of Whidbey and Camano Islands. Future needs are expected to be served by outside surface sources, increasing to 60 percent by 1980.

[b] Based on 70 gpcd and 100 percent served by ground water.

[c] Supplied by Anacortes.

[d] Figures are rounded.

TABLE 13-9. Projected water use (2000).

	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
MUNICIPAL USE[a]					
Oak Harbor	11,350	---	---	---	---
Naval Air Station	8,000	---	---	---	---
Coupeville	3,000	---	---	---	---
Langley, Clinton, Camano, and other rural community systems	9,500	---	---	---	---
Subtotal	31,850	5.0	7.0	1.7	2.4
RURAL-INDIVIDUAL USE	4,350	---	---	0.4[b]	0.6
INDUSTRIAL USE					
Naval Air Station[c]	---	3.0	4.0	---	---
Total[d]	36,200	8.0	11.0	2.1	3.0

[a] Because adequate ground water sources are not available on the islands, it is expected that future growth will be supplied almost entirely by surface sources outside of Whidbey and Camano Islands. Future needs are expected to be served by outside surface sources, increasing to 75 percent by 2000.

[b] Based on 90 gpcd and 100 percent served by ground water.

[c] Supplied by Anacortes.

[d] Figures are rounded.

TABLE 13-10. Projected water use (2020).

	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE[a]					
Oak Harbor	18,550	—	—	—	—
Naval Air Station	10,000	—	—	—	—
Coupeville	4,000	—	—	—	—
Langley, Clinton, Camano, and other rural community systems	12,000	—	—	—	—
Subtotal	44,550	9.3	13.0	1.0	1.4
RURAL-INDIVIDUAL USE	4,950	—	—	0.6[b]	0.8
INDUSTRIAL USE					
Naval Air Station[c]	—	4.0	5.0	—	—
Total[d]	49,500	13.3	18.0	1.6	2.2

[a]By the year 2020, growth will be supplied almost entirely by surface sources outside of Whidbey and Camano Islands.

[b]Based on 110 gpcd and 100 percent served by ground water.

[c]Supplied by Anacortes.

[d]Figures are rounded.

TABLE 13-11. Summary of projected water needs.

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	16,185	1.0	1.4	1.1	2.2	2.1	3.6
	1980	22,900	2.6	3.6	1.8	2.5	4.4	6.1
	2000	31,860	5.0	7.0	1.7	2.4	6.7	9.4
	2020	44,550	9.3	13.0	1.0	1.4	10.3	14.4
Industrial	1965	—	1.5	1.8	—	—	1.5	1.8
	1980	—	2.0	2.5	—	—	2.0	2.5
	2000	—	3.0	4.0	—	—	3.0	4.0
	2020	—	4.0	5.0	—	—	4.0	5.0
Rural-Individual	1965	4,015	—	—	0.2	0.4	0.2	0.4
	1980	4,000	—	—	0.3	0.4	0.3	0.4
	2000	4,360	—	—	0.4	0.6	0.4	0.6
	2020	4,950	—	—	0.6	0.8	0.6	0.8
Totals	1965	20,200	2.5	3.2	1.3	2.6	3.8	5.8
	1980	26,900	4.6	6.1	2.1	2.9	6.7	9.0
	2000	36,200	8.0	11.0	2.1	3.0	10.1	14.0
	2020	49,500	13.3	18.0	1.6	2.2	14.9	20.2

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 14 mgd by the year 2020. This is an increase of approximately 10 mgd over the 1965 average use. Optimum or peak water requirements will be almost one and one-half times this average or nearly 34 mgd. Tables 2-12 or 2-13, the Area Plans, summarize the basins' annual average and optimum requirement in relation to the remainder of the Area. Table 13-12, M&I Water Supply Needs, reviews the needs of the major water systems and/or users in the basin.

Present water facilities on Whidbey and Camano Islands with one exception consist of many small individual systems served from ground water sources. The exception is Whidbey Island Naval Air Station which uses surface water supplied via pipeline from Anacortes.

Existing supplies on the Islands are not considered to be adequate beyond 1985. Until this time, ground water is expected to meet existing needs. Potential alternative sources of this additional water are the Anacortes water system, the Skagit River, the Stillaguamish River, and desalination, although the latter alternative is considerably more costly at the present time. Desalination is discussed in more detail in the San Juan Islands Means to Satisfy Needs Section.

BASIN PLANS

Due to the present demand on Whidbey and Camano Islands for recreation and retirement home sites, and the anticipated population increase, county-wide or regional services have been considered in both the Selected and Alternative Plans.

The Selected Plan, Table 13-13, calls for the use of existing water facilities until 1980. At this time, it suggests the Whidbey Island and Camano Island populations form separate service areas to entirely serve each island. Whidbey Island could purchase water from the Anacortes Water System to meet all needs through 2020 and beyond. Camano Island would then receive water developed by the county services from horizontal wells located in the Stillaguamish River. In both cases existing bridges would provide support to the islands for the transmission lines.

The Alternative Plan, Table 13-14, is to develop immediately, by a county services system, a source on the Skagit River (to supply Whidbey Island) and a source on the Stillaguamish River to supply Camano Island. The development of individual sources for both islands has the benefit of not having the need of an underwater crossing for the transmission line between the two islands.

The Selected Plan, although nearlv $2 million more expensive, has been chosen because of recommendations from recent engineering studies.

Storage and distribution costs will remain the same for both plans. These costs are shown in Tables 2-12 and 2-13, the Area Selected and Alternative Plans, respectively.

Table 13-12, Summary of Projected Water Needs, shows the low level of need to 2020 from all sources. On this basis, a surface water source is recommended as the least expensive alternative, and still be adequate to satisfy the projected needs.

FINANCE

Annual income as taken from Tables 2-12 and 2-13 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

Year	Bond Service Available (x $1,000)	Annual Amortized Cost (x $1,000) Selected Plan	Alternative Plan
1965	$ 90	$ 73	$ 67
1980	161	93	173
2000	250	281	158
2020	350	218	214

TABLE 13-12. M & I Water Supply—Capital Improvements Whidbey-Camano Islands

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	4,540	7,500	11,350	18,550
OAK HARBOR				
Optimum	3.0	4.9	7.5	12.2
Capital Improvements	2.3	1.9	2.6	4.7
Population Served	4,800	6,000	8,000	10,000
NAVAL AIR STATION				
Optimum	5.0	6.4	9.3	11.6
Capital Improvements	2.2	1.4	2.9	2.3
Population Served	1,200	2,000	3,000	4,000
COUPEVILLE				
Optimum	0.8	1.3	2.0	2.6
Capital Improvements	0.6	0.5	0.7	0.6
Population Served	5,645	7,400	9,500	12,000
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	3.7	4.9	6.3	7.9
Capital Improvements	2.4	1.2	1.4	1.6
Population Served	16,185	22,900	31,850	44,550
TOTAL				
Capital Improvements	8	5	8	9

NOTE: Figures are rounded.

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that by 1980 or sooner Whidbey and Camano Islands will be unable to bond for the required water supply development, and future construction would involve extraordinary and excessive financial burden in relation to the islands' economic resources.

TABLE 13-13. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Whidbey—Camano Islands

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
OAK HARBOR												
Present	GW	Local Ground Water	Exist.	0.4	1	1				4		47
Present	GW	ADD: 2.3 Local Ground Water	1965		2	2	138					
1980	GW	Local Ground Water	1975	1.4	2	2	120			15		164
					5	5	$ 258					
NAVAL AIR STATION												
Present	GW	Local Ground Water	Exist.	2.5	1	1						292
Present	SW	Purchase from Anacortes	Exist.		2	2				26		
Present	SW	ADD: 2.2mgd from Anacortes	1965		2	2	286	165				
1980	GW	Local Ground Water	1975	3.2	2	2	120			34		374
					7	7	$ 406	165				
COUPEVILLE												
Present	GW	Local Ground Water	Exist.	0.1	0.2	0.2				1		12
Present	GW	ADD: 0.6 Local Ground Water	1965		0.6	0.6	36					
1980	GW	Local Ground Water	1975	0.4	0.5	0.5	30			4		47
					1.3	1.3	$ 66					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water	Exist.	0.6	1	1				6		
Present	GW	ADD: 2.4 Local Ground Water	1965		2	2	144					70
1980	GW	Local Ground Water	1975	14	2	2	72			15		164
					5	5	$ 216					
OAK HARBOR—NAVAL AIR STATION COUPEVILLE—SMALL & RURAL COMMUNITY SYSTEMS												
ALL SUPPLIED BY ISLAND COUNTY SERVICE AREAS												
2000	SW	[a]25mgd from Anacortes to Whidbey Is.	1985	10	25	25	3,263	1,883		102		1,168
2020	SW	Stillaguamish R., Intake & Treat for Camano Island	2005	14	9	9	1,196	690		150		1,636
					34	34	$4,459	$2,573				
SELECTED BASIN PLAN TOTAL							$8,143					

[a] Initial development.

[b] Does not include storage and distribution costs; See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 13–14. M & I Water Supply Use Planning–Present to year 2020 Alternative Basin Plan Whidbey–Camano Islands

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Optimum Capacity MGD: Supply	Optimum Capacity MGD: Transm.	1967 Thousand Dollars, Amortized Capital Cost[b]: Supply & Transm.	Amortized Capital Cost[b]: Treatment	Amortized Capital Cost[b]: Iron Removal	Maintenance and Oper.: Pumping Power	Maintenance and Oper.: Chem.	Total Annual Income
PLAN 2												
OAK HARBOR												
Present	GW	Local Ground Water	Exist.	0.4	1	1				4		47
Present	GW	ADD: 2.3 Local Ground Water	1965		2	2	138					
							$ 138					
NAVAL AIR STATION												
Present	SW	Purchase from Anacortes	Exist.	2.5	2	2						292
Present	GW	Local Ground Water	Exist.		1	1				26		
Present	SW	ADD: 2.2 from Anacortes	1965		2	2	286					
					5	5	$ 286					
COUPEVILLE												
Present	GW	Local Ground Water	Exist.	0.1	0.2	0.2				1		12
Present	GW	ADD: 0.6 Local Ground Water	1965		0.6	0.6	36					
					0.8	0.8	$ 36					
OAK HARBOR–NAVAL AIR STATION COUPEVILLE												
SUPPLIED BY ANACORTES												
1980	SW	[a] Skagit River (Anacortes)	1970	5	13	13	1,638	945		52		584
2000	SW	Skagit River (Anacortes)	1995	8	6	6	806	465		80		934
2020	SW	Skagit River (Anacortes)	2015	12	7	7	988	570		120		1,402
					26	26	$ 3,432	$ 1,980				
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water	Exist.	0.6	1.3	1.3				6		
Present	GW	ADD: 2.4 Local Ground Water	1965		2.4	2.4	144					70
1980	GW	[a] Stillaguamish River, Intake & Treat.	1975	1.4	1.2	1.2	152			14		164
2000	SW	Stillaguamish River, Intake & Treat.	1995	2.0	1.4	1.4	182			21		234
2020	SW	Stillaguamish River, Intake & Treat.	2015	2.8	1.6	1.6	208			29		327
					8	8	$ 686					
ALTERNATIVE BASIN PLAN TOTAL							$6,558					

[a] Initial development.

[b] Does not include storage and distribution costs; See Area Means to Satisfy Needs section.

[c] All figures are rounded.

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GLOSSARY

ACRE-FOOT (ac-ft.). – A unit commonly used for measuring the volume of water or sediment; equal to the quantity of water required to cover one acre to a depth of one foot and equal to 43,560 cubic feet or 325,851 gallons.

ALLUVIUM – Soil material, such as sand, silt, or clay, that has been deposited by water.

AQUIFER – A rock formation, bed, or zone containing water that is available to wells. An aquifer may be referred to as a water-bearing formation or water-bearing bed.

ARTESIAN WATER – Ground water under sufficient pressure to rise above the level at which the water-bearing bed is reached in a well. The pressure in such an aquifer commonly is called artesian pressure, and the rock containing artesian water is an artesian aquifer.

BASE FLOW – See Base Runoff

BASE RUNOFF – Sustained or fair weather runoff. In most streams, base runoff is composed largely of ground water effluent. The term base flow is often used in the same sense as base runoff. However, the distinction is the same as that between streamflow and runoff. When the concept in the terms base flow and base runoff is that of the natural flow in a stream, base runoff is the logical term.

BASIN – A geographic area drained by a single major stream.

cfs (Cubic Foot per Second) – A unit of discharge for measurement of flowing liquid equal to a flow of one cubic foot per second past a given section. Also called second-foot.

CAPITAL EXPENDITURES – Outlays for plant and equipment which are normally charged to fixed asset accounts.

CHANNEL STORAGE – The volume of water at a given time in the channel or over the flood plain of the streams in a drainage basin or river reach. Channel storage is sometimes significant during the progress of a flood event.

CHLORINATION – The application of chlorine to water, sewage, or industrial wastes generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

COLIFORM BACTERIA – A species of genus escherichia bacteria, normal inhabitant of the intestine of man and all vertebrates.

CONSTRUCTION COST – The total cost of construction, including real estate, engineering, design, administration and supervision.

CONSUMPTIVE USE – The quantity of water discharged to the atmosphere or incorporated in the products in the process of vegetative growth, food processing, industrial processes, or other use. Hence, the amount of water no longer directly available.

CONSUMPTIVE USE IRRIGATION – All withdrawals are considered to be consumptive unless the full amount of the withdrawal is returned to the source.

COOLING WATER CONSUMPTION (POWER) – The cooling water which is lost to the atmosphere, caused primarily by evaporation due to the temperature rise in the cooling water as it passes through the condenser. The amount of consumption (loss) is dependent on the type of cooling employed – flow-through, cooling ponds, or cooling tower.

COOLING WATER LOAD – Heat energy dissipated by the cooling water.

COOLING WATER REQUIRED (POWER) – The amount of water needed to pass through the condensing unit in order to condense the steam to water.

CORRELATION – The process of establishing a relation between two or more related variables. It is a simple correlation if there is only one independent variable; multiple correlation if there is more than one independent variable.

CUBIC FEET PER SECOND PER DAY (cfs-day) – The volume of water represented by a flow of one cubic foot per second for 24 hours. It equals 86,400 cubic feet, 1.983471 acre-feet, or 646,317 gallons.

CUBIC FEET PER SECOND (cfs)– A unit expressing rate of discharge. One cubic foot per second is equal to the discharge of a stream having a cross section of one square foot and flowing at an average velocity of one foot per second. It also equals a rate of 448.8 gallons per minute.

DO (Dissolved Oxygen) – The oxygen dissolved in sewage water or other liquid, usually expressed in milligrams per liter or percent of saturation.

DEMAND–A need or desire. (Differs from the usual economic definition of demand under which a need is not necessarily reflected in a demand).

DISCHARGE – In its simplest concept, discharge means outflow; therefore, the use of this term is not restricted as to course or location and it can be used to describe the flow of water from a pipe or a drainage basin.

DISCHARGE, AVERAGE – The arithmetic average of the annual discharges for all complete water years of record whether or not they are consecutive. The term "average" is generally reserved for average of record and "mean" is used for averages of shorter periods; namely, daily mean discharge.

DIVERSION – The taking of water from a stream or other body of water into a canal, pipe, or other conduit.

DRAINAGE AREA – The drainage area of a stream, measured in a horizontal plane, which is enclosed by a drainage divide.

DRAINAGE BASIN – A part of the surface of the earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

DRAINAGE DIVIDE – The line of highest elevations which separates adjoining drainage basins.

DRAWDOWN (GROUND WATER) – The depression or decline of the water level in a pumped well or in nearby wells caused by pumping. It is the vertical distance between the static and the pumping level at the well.

DROUGHT – A period of deficient precipitation or runoff extending over an indefinite number of days, but with no set standard by which to determine the amount of deficiency needed to constitute a drought. Thus, there is no universally accepted quantitative definition of drought; generally, each investigator establishes his own definition.

ECONOMIC BASE STUDY – A study which evaluates the economic structure of the region to provide economic projections necessary for the appraisal of future water resource needs.

EFFECTIVE PRECIPITATION – That part of the precipitation falling on a crop area that is effective in meeting the consumptive use requirements of the crop.

EUTROPHICATION – The process of overfertilization of a body of water by nutrients which produce more organic matter than the self-purification processes can overcome.

FARM–A area operated as a unit of ten or more acres from which the sale of agricultural products totaled $50 or more annually, or an area operated as a unit of less than ten acres from which the sale of agricultural products total $250 or more annually during the previous year.

FLOOD – Any relatively high streamflow or an overflow or inundation that comes from a river or other body of water and causes or threatens damage.

FLOOD PEAK – The highest value of the stage or discharge attained by a flood; thus, peak stage or peak discharge. Flood crest has nearly the same meaning but, since it connotes the top of the flood wave, it is properly used only in referring to stage.

FLOOD PLAIN – A strip of relatively smooth land bordering a stream that has been or is subject to flooding. It is called a "living" flood plain if it is overflowed in times of high water, but a "fossil" flood plain if it is beyond the reach of the highest flood.

FLOOD, PROBABLE MAXIMUM – The largest flood for which there is any reasonable expectancy in the geographical region involved.

FLOOD STAGE – The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the stage is observed.

FLOWING WELL – An artesian well having sufficient head to discharge water above the land surface.

FOREST LAND – Land which is at least 10 percent stocked by forest trees of any size and land from which the trees have been removed to less than 10 percent stocking but which has not been developed for other use.

gpcd – Gallons per capita per day.

gpd – Gallons per day.

GAGING STATION – A particular site on a stream, canal, lake or reservoir where systematic observations of gage height or discharge are obtained.

GAGING STATION NUMBER – An eight-digit number assigned to a gaging station which identifies the station in downstream order relative to other gaging stations and sites where streamflow data are collected. The first two digits designate the major drainage basin, the others the station.

GROUND (GW)–Water in the ground that is in the zone of saturation from which wells, springs and ground water runoff are supplied.

GROUND WATER OUTFLOW – That part of the discharge from a drainage basin that occurs through the ground water. The term "underflow" is often used to describe the ground water outflow that takes place in valley alluvium (instead of the surface channel) and thus is not measured at a gaging station.

HARDNESS – A characteristic of water; chiefly due to the existence there-in of the carbonates and sulfates and occasionally nitrates and chlorides of calcium, iron, and magnesium; which causes "curdling" of the water when soap is used, increased consumption of soap, deposition of scale in boilers, injurious effects in some industrial processes, and sometimes objectionable taste in the water. It is commonly computed from the amounts of calcium and magnesium in the water and expressed as equivalent calcium carbonate.

HYDROGEN ION CONCENTRATION – The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithm of the reciprocal of the hydrogen ion concentration.

INDUSTRIAL WATER – The industrial category includes those major water-using industries whose size is related to a significantly larger population than that of the local area and whose water needs are normally supplied through a municipal distribution system. For the purposes of this analysis, these industries are the following:

Pulp and paper
Other major forest products
Food processing
Petroleum processing
Primary metals
Thermal and nuclear power

INFILTRATION – The flow of the fluid into a substance through pores or small openings. It connotes flow into a substance in contradistinction to the word percolation, which connotes flow through a porous substance.

INFILTRATION CAPACITY – The maximum rate at which the soil, when in a given condition, can absorb falling rain or melting snow.

INTERCEPTION (HYDROLOGY)–The process of storing rain or snow on leaves and branches or other objects which eventually evaporates back to the air.

JTU (Jackson Turbidity Units) – The JTU, as the name implies, is a measurement of the turbidity, or lack of transparency, of water. It is measured by lighting a candle under a cylindrical transparent glass tube and then pouring a sample of water into the tube until an observer looking from the top of the tube cannot see the image of the candle flame. The number of JTU's varies inversely with the height of the sample (e.g. a sample which measures 2.3 cm has a turbidity of 1,000 JTU's whereas a sample measuring 72.9 cm has a turbidity of 25 JTU's.)

LAND AREA – The solid portion of the earth's surface including bodies of water less than 40 acres and streams of less than 1/8 mile wide.

LAND USE – Primary occupier of a tract of land grouped into classes with similar characteristics, i.e., cropland, rangeland, forest land, or other.

LOW FLOW FREQUENCY CURVE – A graph showing the magnitude and frequency of minimum flows for a period of given length. Frequency is usually expressed as the average interval, in years, between recurrences of an annual minimum flow equal to, or less than that shown by the magnitude scale.

mgd – Millions of gallons per day.

mg/l – Milligrams pper liter.

MPN (Most probable number) – In the testing of bacterial density by the dilution method, that number of organisms per unit volume which, in accordance with statistical theory, would be more likely than any other possible number to yield the observed test result or which would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml.

MAXIMUM WATER SURFACE (RESERVOIR) – The maximum water surface elevation is the highest water surface elevation for which the dam is designed. It is also the top of the surcharge capacity.

MUNICIPAL WATER – The municipal category includes not only urban domestic water use but also those other civic, commercial, and small industrial uses which are typically supplied through a municipal distribution system and the magnitude of which is related to local population.

NEED–The lack of something usefull, required, or desired; the lack of water or water system facilities also adaptions and betterments and improvements.

NON–CONSUMPTIVE. Non-consumptive uses related to surface water only, are where no water is divereted from the confines of the surface water source area or channel, where the waters pass over, under, around or through an on stream project, or when being diverted (effectively) at the upstream edge of a project and being returned (effectively) to the channel at the downstream edge of project. It is considered non-consumptive water use when water diverted from a surface water source is returned to the same source at any location upstream from the point of diversion. Transportation losses, evaporation, seepage, are not considered consumptive.

NORMAL ANNUAL PRECIPITATION – Average annual precipitation during the base period, 1931-1960 inclusive.

OPERATION AND MAINTENANCE COSTS – Average annual costs of project operation and normal maintenance.

OPTIMUM WATER REQUIREMENT – 658 gallons per capita per day plus maximum monthly industrial water use.

pH – See Hydrogen ion concentration.

PARTIALLY CONSUMPTIVE. The use is partially consumptive when, in the case of surface water, the diverted water is returned to the source 25 feet or more downstream. Partially consumptive for ground water is the condition when the full amount withdrawn is returned to the same source aquifer(s).

PEAK – The maximum water used in a stated period of time. Usually it is the maximum amount experienced over an interval of a year, month, week, or day. It is used interchangeably with peak demand.

PERCOLATION – The movement, under hydrostatic pressure, of water through the interstices of a rock or soil.

PRECIPITATION – As used in hydrology, precipitation is the discharge of water, in the liquid or solid state, out of the atmosphere, generally upon a land or water surface. It is the common process by which atmospheric water becomes surface or subsurface water. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated.

RAINFALL – The quantity of water that falls as rain. Not synonymous with precipitation.

RECHARGE (GROUND WATER) – The addition of water to the zone of saturation. Infiltration of precipitation and its movement to the water table is one form of natural recharge; injection of water into an aquifer through wells is one form of artificial recharge.

RECURRENCE INTERVAL – The average number of years within which a given event will be equaled or exceeded.

RESERVOIR – A pond, lake or basin, either natural or artificial, for the storage, regulation, and control of water.

RESERVOIR, RE-REGULATING – A reservoir used to regulate the outflow from an upstream reservoir.

RESERVOIR, SINGLE-PURPOSE – A reservoir planned to serve only one purpose.

RIPARIAN – Pertaining to the banks of streams, lakes or tidewater.

RIVER REACH – Any defined length of a river.

RUNOFF – That part of rainfall or other precipitation that reaches watercourses or drainage systems.

RUNOFF, ADJUSTED MEAN ANNUAL – Average annual runoff adjusted for length of record by comparison with record at pivot stations.

RURAL POPULATION–All population not classed as urban (Rural population is divided into rural farm and rural nonfarm population.)

SALINITY – The relative concentration of salts, usually sodium chloride, in a given water sample. It is usually expressed in terms of the number of parts per thousand of chlorine (Cl). Parts per thousand = o/oo.

SEDIMENT – Fragmental or clastic mineral particles derived from soil, alluvial, and rock materials by processes of erosion; and transported by water, wind, ice, and gravity. A special kind of sediment is generated by precipitation of solids from solution (i.e., calcium carbonate, iron oxides). Excluded from the definition is vegetation, wood, bacterial and algal slimes, extraneous light-weight artifically-made substances such as trash, plastics, flue ash, dyes, and semi-solids.

SEDIMENT DISCHARGE – The rate at which dry weight of sediment passes a section of a stream or the quantity of sediment, as measured by dry weight or by volume, that is discharged in a given time.

SERVICE AREAS – An area described for planning purposes whose boundaries would include the future population or industrial activities which could logically and functionally obtain water supply from a central or integrated system or where the problems are so interrelated that the planning should be done on an integrated basis.

SILT – Individual mineral particles in a soil that range in diameter from the upper limit of clay (0.002 millimeters) to the lower limit of very fine sand (0.05 millimeters). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

STREAM INTERMITTENT – A stream that flows only part of the time or through only part of its reach.

STREAM PERENNIAL – A stream that flows continuously.

STREAMFLOW – The discharge that occurs in a natural channel. Although the term discharge can be applied to the flow of a canal, the word streamflow uniquely describes the discharge in a surface stream course. Streamflow is a more general term than runoff, as streamflow may be applied to discharge whether or not it is affected by diversion or population.

STREAMFLOW REGULATION – The artificial manipulation of the flow of a stream.

STORAGE – Water naturally or artificially impounded in surface or underground reservoirs.

STORAGE CAPACITY, ACTIVE (USABLE) – The volume normally available for release from a reservoir below the stage of the maximum controllable level. (Total capacity less inactive and dead capacity.)

STORAGE CAPACITY, CONSERVATION – Storage capacity available for all useful purposes such as municipal water supply, power, irrigation, recreation, fish and wildlife, etc., excluding joint use and exclusive flood control capacity.

STORAGE CAPACITY, DEAD – The volume of a reservoir below the sill or invert of the lowest outlet.

STORAGE CAPACITY, INACTIVE – The portion of live storage capacity from which water normally will not be withdrawn, in compliance with operating agreements or restrictions.

S.W.–Surface Water.

TDS – Total dissolved solids.

TOTAL ANNUAL AVERAGE COST–The sum of the annual equivalent of the fixed cost, the annual operation and maintenance costs, and the annual equivalent of major replacement costs.

TOURIST–An individual participating in recreation within a basin but residing outside that basin.

TURBIDITY – (1) A condition of a liquid due to fine visible material in suspension which may not be of sufficient size to be seen as individual particles by the naked eye, but which prevents the passage of light through the liquid. (2) A measure of fine suspended matter (usually colloidal) in liquids.

VALUE ADDED – Wages and salaries, interest payments, profits, and the like. Often represents the contribution of industries to the gross basin product used to measure production growth.

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AD-A037 574 PACIFIC NORTHWEST RIVER BASINS COMMISSION VANCOUVER WASH F/G 8/6
COMPREHENSIVE STUDY OF WATER AND RELATED LAND RESOURCES. PUGET --ETC(U)
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TABLE 4-10. Summary of projected water needs

System		Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	40,230	3.5	4.2	0.8	1.1	4.3	5.3
	1980	48,200	8.4	11.8	0.8	1.1	9.2	12.9
	2000	69,200	13.0	18.3	1.5	2.1	14.5	20.4
	2020	100,500	20.6	28.9	2.6	3.6	23.2	32.5
Industrial	1965	—	22.8	26.9	—	—	22.8	26.9
	1980	—	38.9	46.9	—	—	38.9	46.9
	2000	—	60.9	74.3	—	—	60.9	74.3
	2020	—	91.2	113.0	—	—	91.2	113.0
Rural–Individual	1965	15,270	0.1	0.2	0.8	1.6	0.9	1.8
	1980	16,000	—	—	1.1	1.5	1.1	1.5
	2000	17,300	—	—	1.6	2.2	1.6	2.2
	2020	17,700	—	—	2.0	2.8	2.0	2.8
Totals	1965	55,500	26.4	31.3	1.6	2.7	28.0	34.0
	1980	64,200	47.3	58.7	1.9	2.6	49.2	61.3
	2000	86,500	73.9	92.6	3.1	4.3	77.0	96.9
	2020	118,200	111.8	141.9	4.6	6.4	116.4	148.3

Note: All usage figures are rounded to one decimal place.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 117 mgd by the year 2020. This is an increase of approximately 90 mgd over the 1965 average use. Optimum or peak water requirements will be nearly 180 mgd. Tables 2-10 or 2-11, the Area Plans, summarize the Basins' annual average and optimum requirement in relation to the remainder of the Area. Table 4-11, Municipal and Industrial Water Supply Needs, reviews the needs of the major water systems and/or users in the Basins.

The city of Anacortes and the Skagit County PUD No. 1, major water purveyors of the Skagit-Samish Basins, supply approximately 87 percent of the annual average water use. Table 4-10 summarizes the present and future needs for the Basins. The major water users will be centered near the more urbanized centers and will receive water from presently developed and expanded sources.

The smaller rural communities are expected to continue using ground water sources as their major source of water. The exception will be when one of the larger systems can feasibly extend its distribution system into the more sparsely populated areas. Self-supplied industry using both surface and ground water will continue expanding existing systems. The small and rural communities and self-supplied industry presently use only about 13 percent of the total Basin water.

The municipal and industrial water needs projected for 2020 can be met by water available in the Basins without need for storage. Although a plentiful source of surface water is available, the projected population and industrial growth will require larger systems to satisfy requirements.

BASIN PLANS

The Selected Basin Plan, as recommended is to provide enlargement and expansion of existing water systems. Table 4-12 defines the plan and includes

TABLE 4-11. Municipal and industrial water supply—capital improvements, Skagit-Samish Basins

	M.G.D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	10,000	13,000	20,000	30,000
ANACORTES				
Optimum	21.8	37.0	50.8	68.5
Capital improvements	1.0	15.2	13.8	17.7
Population Served	23,500	30,000	40,000	55,000
SKAGIT CO. PUD No. 1				
Optimum	24.7	33.9	52.2	81.0
Capital improvements	5.2	9.2	18.3	28.8
Population Served	6,730	5,200	9,200	15,500
SMALL AND RURAL COMMUNITY SYSTEMS				
Optimum	4.4	3.4	6.1	10.2
Capital improvements	3.1	–	2.7	4.1
Population Served	–	–	–	–
SELF-SUPPLIED INDUSTRY				
Optimum	2.5	4.3	8.7	16.3
Capital improvements	0.5	1.8	4.4	7.6
Population Served	40,230	48,200	69,200	100,500
TOTAL CAPITAL IMPROVEMENTS	10	26	39	58

Note: Figures are rounded.

supply and transmission, treatment, pumping, chemical, and annual income as projected by the Municipal and Industrial Water Supply and Water Quality Control Technical Committee. Table 2-12 includes the storage and distribution costs for the Basins.

The Alternative Basin Plan Table 4-13 calls for the use of Skagit River water by both Anacortes and the Skagit County PUD No. 1. The minimum record flow of the Skagit River, 1942 at Mount Vernon, was 1,770 mgd. At this rate, the Skagit River would be able to supply both systems with no problem. This plan was placed as an alternative to the selected plan for several reasons: (1) Anacortes has an existing intake and treatment plant on the Skagit River; (2) the Skagit County PUD No. 1 presently receives most of its water from a watershed and has proposed expanding it (The watershed water would not require the extensive treatment as would the Skagit River); (3) it would have required considerable funds to redevelop the amount of water already available. This may not be within the present annual income abilities of the system.

Anacortes, currently operating near capacity, is able to supply a peak maximum of 21 mgd to municipal and industrial consumers. The existing system, drawing from horizontal wells in the Skagit River, receives large amounts of ground water, along with the river water, which is very high in iron. This present system will be phased out in favor of a river water intake and complete treatment plant. Upon completion of the new source, the horizontal wells will be used only for meeting peaks and standby service as needed.

The Skagit County PUD No. 1, operating the Cultus Mountain watershed, should be able to meet all anticipated needs through 2020 with the additions planned for the watershed. If operation continues as in the past, the PUD will be able to deliver adequate quality water without treatment.

Surface and ground water supplies can be economically utilized by self-supplied industry, rural-individual, or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Table 4-10, Summary of Projected Water Needs, shows the level of need to 2020 from all sources.

FINANCE

Annual income as taken from Table 2-10 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20% of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years.

		Annual Amortized Cost (X $1,000)	
Year	Annual Bond Service Available (X$1,000)	Selected Plan	Alternative Plan
1965	$ 675	$157	$156
1980	1,170	278	206
2000	1,850	494	421
2020	2,480	758	671

As above figures indicate, the Skagit-Samish Basins will be able to finance adequately all projected future developments without excessive financial burden in relation to the Basin economy or an increase in water rates.

TABLE 4-12. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Skagit-Samish Basins

					OPTIMUM CAPACITY M G D[d]		1967 THOUSAND DOLLARS					
							AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
ANACORTES												
Present	SW	Skagit River—1 Ranney Wells and Raw Water Diversion and Treatment	Exist.	15	20.8	30				160	6	1,752
1980	SW	River Intake and Treatment Plant Expans.	1975	28	16	16	1,950	1,125		158	11	3,270
2000	SW	River Intake and Treatment Plant Expans.	1995	40	13	13	1,950	1,125		158	16	4,672
2020	SW	River Intake and Treatment Plant Expans.	2015	54	19	19	2,320	1,350		189	22	6,307
					69	78	$ 6,220	$3,600				
ANACORTES SELECTED PLAN TOTAL							$9,820					
SKAGIT CO' PUD NO.1												
Present	SW	Cultus MTN Watershed	Exist.	9	13	13						
Present	SW	Skagit River Intake and Treatment	Exist.		6	6				93	3	1,061
Present	GW	Well	Exist.		1	1						
1985	SW	Present Need: Add Watershed—Cultus MTN	1985		5	5	650	375				
1980	SW	[a] Watershed—Initial Stage, Day Creek Watershed Development	1970	15	10	10	1,300	750		158	6	1,725
2000	SW	Watershed—Initial, Day Creek Watershed Development	1990	28	20	20	2,600	1,500		270	10	3,037
2020	SW	Watershed—Initial Stage, Day Creek Watershed Development	2010	43	30	30	3,800	2,250		446	17	3,531
					85	85	$8,350	$4,875				
SKAGIT CO. PUD NO. 1 SELECTED PLAN TOTAL							$13,225					
SMALL & RURAL COMMUNITIES												
Present	GW	Local GW	Exist.	1	1	1				0		117
1985	GW	ADD: Local GW (Present Needs)	1985	·	3	3	180					
1980		No Additional Need								1		117
2000	GW	Local GW Development	1990	2	3	3	180			2		234
2020	GW	Local GW Development	2010	4	4	4	240			3		467
SMALL & RURAL COMMUNITIES SELECTED PLAN TOTAL					11	11	$600					
SELF SUPPLIES INDUSTRY												
Present		Surface or Ground Source Development	Exist.	2	3	3				2		234
1980		Surface or Ground Source Development	1980	3	2	2	180	135		3		350
2000		Surface or Ground Source Development	2000	6	4	4	440	330		6		701
2020		Surface or Ground Source Development	2020	11	8	8	760	570		12		1,285
					17	17	$1,380	$1,035				
SELF SUPPLIED INDUSTRY SELECTED PLAN TOTAL							$2,415					
SELECTED BASIN PLAN TOTAL							$ 26,080					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.5 gpm per service connection plus the maximum industrial monthly demands.

TABLE 4-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Skagit—Samish Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Optimum Capacity M G D[d]: Supply	Optimum Capacity M G D[d]: Transm.	Thousand 1967 Dollars, Amortized Capital Cost[b]: Supply & Transm.	Amortized Capital Cost[b]: Treat-ment	Amortized Capital Cost[b]: Iron Removal	Maintenance and Oper.: Pumping Power	Maintenance and Oper.: Chem.	Total Annual Income
ANACORTES												
Present	SW	Skagit River—2 Ranney Wells and Raw Water—Intake and Treatment Plant	Exist.	15	20.8	30				160	6	1,752
1980	GW	Skagit River—Local Wells	1968	28	16	16	900			158		3,270
2000	GW	Skagit River—Local Wells	1995	40	13	13	900			158		4,672
2020	GW	Skagit River—Local Wells	2010	54	19	19	1,080			189		6,307
					69	78	$2,880					
ANACORTES ALTERNATIVE PLAN TOTAL							$2,880					
SKAGIT CO. PUD NO. 1												
Present	SW	Cultas MTN Watershed	Exist.	9	13	13				93	3	1,051
Present	SW	Skagit River Intake and Treatment	Exist.		6	6						
Present	GW	Well (Local)	Exist.		1	1						
Present Need		[a]Skagit River—River Intake and Treatment	1965		5	5	650	375		158	6	1,725
1980	SW	Skagit River—River Intake and Treatment	1975	15	10	10	1,300	750		270	10	3,037
2000	SW	Skagit River—River Intake and Treatment	1990	26	20	20	2,600	1,500		445	17	3,531
2020	SW	Skagit River—River Intake and Treatment	2010	43	30	30	3,800	2,250				
					85	85	$ 8,350	$4,875				
SKAGIT CO. PUD NO. 1 ALTERNATIVE PLAN TOTAL							$13,225					
SMALL & RURAL COMMUNITY SYSTEMS (Same as Selected Plan)												
SELF SUPPLIED INDUSTRY (Same as Selected Plan)												
ALTERNATIVE BASIN PLAN TOTAL							$19,120					

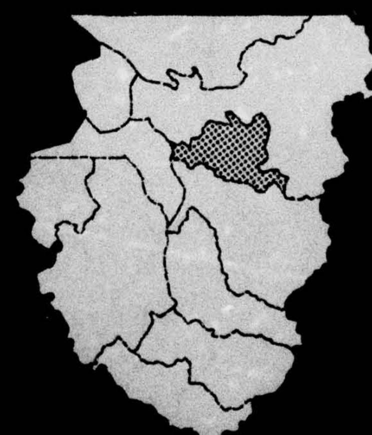
[a] Initial Development.

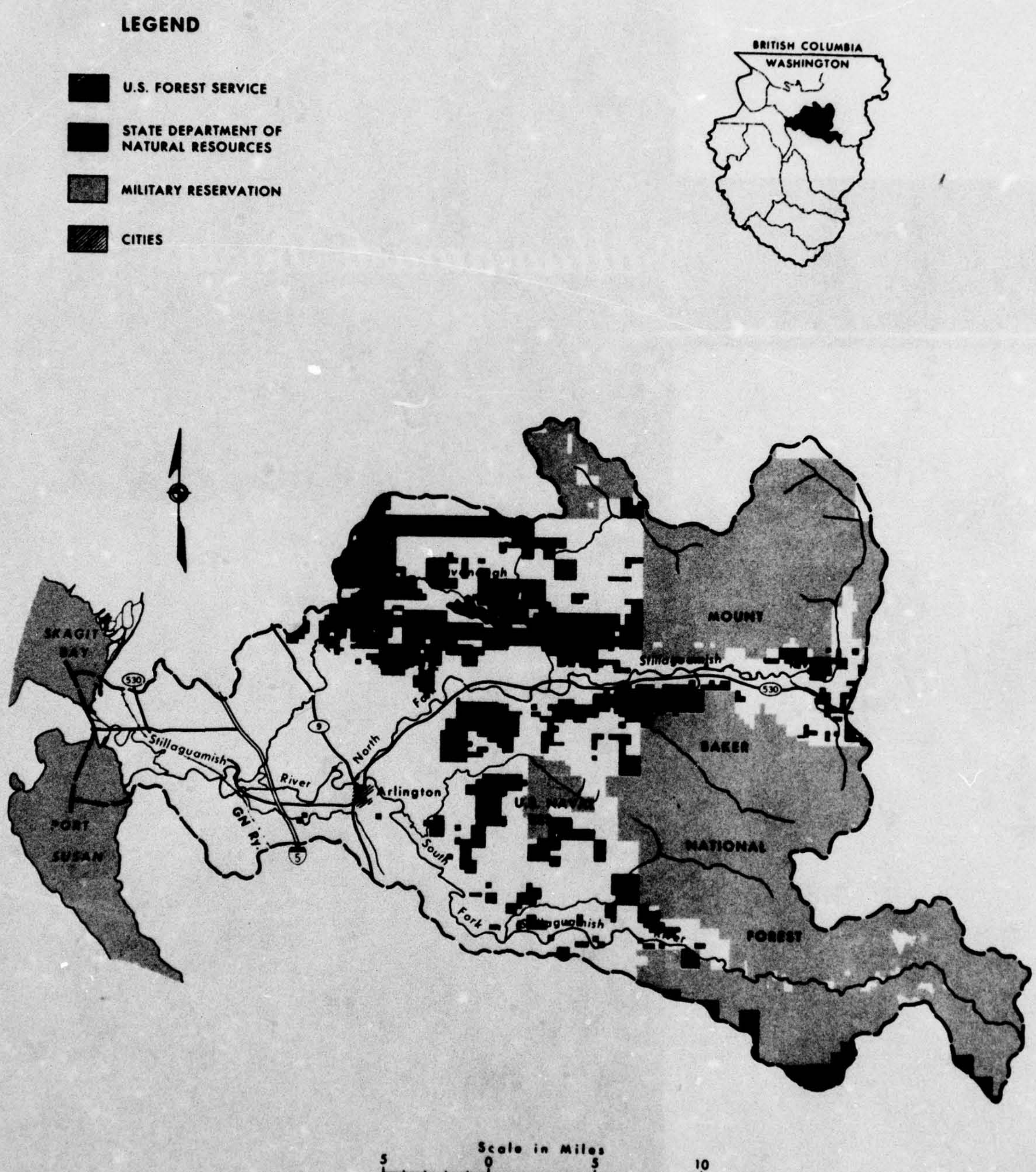
[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.6 gpm per service connection plus the maximum industrial monthly demands.

Stillaguamish Basin





STILLAGUAMISH BASIN

Figure 5-1 Land Ownership

STILLAGUAMISH BASIN

INTRODUCTION

The Stillaguamish Basin, Figure 5-1, located in the northwestern portion of the State and bordered by the Skagit Basin to the north and the Snohomish Basin to the south, occupies some 690 square miles, about three-fourths of which is in Snohomish county. The Basin is only slightly industrialized, but is largely oriented to agricultural and lumbering activities.

Although the basin is sparsely populated and only lightly industrialized today, the population is predicted to more than triple by the year 2020, and industry, mostly in the form of pulp and paper and agricultural enterprises, is expected to increase substantially. Projections indicate that water use will increase by nearly 800 percent, and will far exceed present water supply system capabilities.

GEOGRAPHY

The eastern sector of the basin is a rugged, mountainous area lying mostly within Mount Baker National Forest, with a maximum elevation of 6,854 feet at the summit of Three Fingers Mountain. The western sector comprises mostly tide flats and deltas of the Stillaguamish River. Between these extremes is a topography of river bottoms, gently rolling foothills, level benchlands, narrow canyons, and numerous mountain spurs.

The basin is divided into three principal drainage areas: the North Fork of the Stillaguamish River, the South Fork, and the downstream coastal region. The North Fork, with headwaters in the extreme northeastern sector of the basin 31 miles above Arlington, drains a 286-square-mile area around Finney Peak, Whitehorse Mountain, and adjacent peaks. The South Fork, which heads in the extreme southeastern portion of the basin, and its principal tributaries–Boardman, Canyon, and Jim Creeks–drain an area of about 257 square miles in flowing some 41 miles to the joining of the North and South Forks at Arlington. Below Arlington, the Stillaguamish flows slowly to Puget Sound, draining about 140 square miles of flood plain before it enters Port Susan through Hat Slough, the main outlet.

CLIMATE

Cool, dry summers and mild, wet winters typify the basin climate. Although the Cascade Mountains shield the basin from violent temperature extremes, both temperature and precipitation vary considerably. The mean annual precipitation for the entire watershed is about 76 inches, but ranges from 30 inches in the lowlands near Puget Sound to 170 inches in the mountains. About 70 percent of the precipitation falls during October through March. Maximum and minimum temperatures vary from 32°C (90° F) to -15°C (5° F) at Stanwood and from 40°C (104° F) to -24 °C (-11° F) at Darrington. The average frost-free period varies from 120 days in the higher valleys and foothills to 215 days along the coastal lowlands.

POPULATION

About 18,900 people live in the Stillaguamish Basin. Most settlement has occured in the rural area. The two principal population centers are Arlington, population 2,195 and Stanwood, population 1,240. The eastern part of the Basin is sparsely settled because of the rugged terrain.

ECONOMY

Agriculture, particularly dairy farming, and associated enterprises are the most important industries in the basin and account for more than half the total income. As a result, most of the cropland is used for production of forage to support the livestock industry, though there is now a trend toward the growing and local processing of peas, sweet corn, and other field crops to meet the needs of the expanding Seattle-Tacoma-Everett metropolitan area.

Lumbering, the second major industry in the basin, contributes significantly to the economy. In addition, forest land is used extensively for sports fishing, hunting, and other outdoor recreations that provide a limited income from tourism and related sources.

LAND USE

Conifer forests cover nearly 88 percent of the total acreage in the Basin. About 35,000 acres, most of which are confined to the lowland flood plain of the Stillaguamish River, are used for cropland and represent about 6 percent of the 438,000 total land acres in the Basin. However, urbanization in the form of housing subdivisions is replacing some of the farmland, and promises to replace even more in the future with the development of new industry in nearby Everett. Land use in the Basin is shown in Table 5-1.

TABLE 5-1. General land use.

Use	Acres
Forestland	384,000
Cropland	35,000
Rangeland	1,000
Other land (high, barren)	6,000
Urban buildup	7,000
Inland water	5,000
Total land and inland water	438,000

Source: Appendix III, Hydrology.

PRESENT STATUS

Present water use is well within the supply capabilities of presently developed sources. The basin is largely rural, and a substantial percentage of total water used is supplied from individual wells and small community distribution systems. Ground water sources have been developed as almost the sole source of supply in the basin. No major centralized distribution system is needed, and it is economically more practical to supply ground water.

WATER USE

About 18,400 persons and two industries use a total of about 2.19 mgd. A detailed breakdown of water use in the basin is shown in table 5-2.

Municipal

The present municipal water use of about 0.97 mgd accounts for more than 40 percent of the total basin water consumption. Stanwood, the largest user with 0.40 mgd, serves 1,240 persons and has a per capita water usage of 200 gpd. Arlington uses 0.35 mgd in serving 2,190 persons for a per capita water use of 160 gpd. Several rural community systems use 0.17 mgd, serve 2,010 people, and show a per capita water use of 93 gpd.

Industrial

Industrial water use currently averages about 0.55 mgd, about 25 percent of the total water used in the basin. The two industrial water users, Stokely Van Camp and the Twin City Frozen Food Company, are located in Stanwood. Because these companies process agricultural field products, most of their water use occurs during crop ripening (June to October).

Rural-Individual

Water use by about 12,100 rural-individual users is estimated at 0.67 mgd, more than 30 percent of the total consumption in the Basin. This is based on an estimated average per capita use of 55 gpd.

WATER SUPPLIES

Ground water is used to meet nearly all the basin's municipal and industrial water requirement of 2.19 mgd. (See table 5-2.) All but two of the 14 water systems use ground water as a source and supply about 95 percent (2.07 mgd) of the total water used.

Municipal

Wells and springs supply cities and communities with 0.92 mgd, serving a population of about 6,140 persons. The city of Arlington obtains its water supply from two wells that have a combined maximum yield of about 2.3 mgd. The water supply for the city of Stanwood is drawn from four wells and two spring collection systems. These wells and springs have a maximum total yield of about 4.7 mgd. The community of Silvana obtains its water supply from springs through a 4-inch steel pipeline suspended across Cook Slough.

TABLE 5-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Maximum daily	Ground water usage (mgd) Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Arlington	2,190	---	---	---	0.35	0.55	0.73
Stanwood	2,000	---	---	---	0.40	0.70	0.80
Granite Falls	600	---	---	---	0.05	0.07	0.10
Other rural community systems	2,010	0.05	0.08	0.10	0.12	0.18	0.24
Subtotal	6,800 [b]	0.05	0.08	0.10	0.92	1.50	1.87
RURAL-INDIVIDUAL USE	12,100	0.07 [a]	0.10	0.13	0.60 [a]	0.85	1.21
INDUSTRIAL USE							
Municipally supplied:							
Stanwood:							
Food and kindred	---	---	---	---	0.55	4.00	5.00
Total	18,900	0.12	0.18	0.23	2.07	6.35	8.08

[a]Based on assumed 55 gpcd.

[b] Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

Industrial

The food and associated processors at Stanwood are supplied an average of 0.55 mgd from Stanwood municipal sources.

Rural-Individual

An estimated 12,100 persons are supplied 0.67 mgd from about 3,500 individual rural systems. About 80 percent of these systems are supplied by ground waters.

WATER RIGHTS

The Stillaguamish Basin has a total of 255 recorded water-rights; of these, 191 are surface, and 64 are ground (1966-1967). About 57 percent of all the recorded surface rights in this area involve irrigation. Fish propagation, irrigation, individual and community domestic supply, industrial supply and municipal supply are the major uses in this area with respective total allowable diversions of 34 mgd, 22 mgd, 10 mgd, 8 mgd, and 7 mgd.

Many diversions in the Stillaguamish Basin are subject to low-flow restrictions, and two tributary streams have been closed to further consumptive appropriation.

Nearly half of the total ground water appropriated prime right quantity, or 12 mgd, is applied to irrigation use. Municipal use rights provide for withdrawals of 8 mgd, and industrial and commercial uses may utilize up to 7 mgd.

Two of the larger wells in this area, developed for the city of Stanwood, supply 4 mgd. The city of Arlington withdraws 2.5 mgd from two wells. These wells are located in alluvium adjacent to the Stillaguamish River and indirectly obtain their supply from this source. Table 5-3 shows water rights in the Basin.

TABLE 5-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	6.8	10.6	7.7
Ground water	8.0	0.9	7.2
Total[a]	14.8	11.5	14.9

[a]About 55 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

Water reserves in the Stillaguamish basin, although only partially tapped at present, are capable of supplying all demands in the foreseeable future. The water is generally of excellent quality and is available in sufficient quantity to preclude any water shortage, regardless of growth.

SURFACE WATER

Surface water resources are virtually undeveloped at present; nearly all water consumed in the basin is drawn from ground water sources. Because surface water represents the much greater percentage of water available in the basin, and because of the relatively high quality of the surface water, a substantial resource is available for future users.

Quantity Available

Streams. Two stream discharge stations, one located on the South Fork of the Stillaguamish River near Granite Falls and the other on the North Fork near Arlington, measure runoff from about three-fourths of the basin. During the period of record, 1931 through 1960, stream flows averaged 1,850 cfs on the North Fork (photo 5-1), and 1,085 cfs on the South Fork. Variations in average annual discharge during this same period included high and low flows of 2,615 cfs and 1,120 cfs on the North Fork and 1,466 cfs and 711 cfs on the South Fork. The computed annual flow in the main stem of the Stillaguamish River below Arlington, as estimated from the flow in the North and South Forks, is 3,500 cfs.

PHOTO 5-1. The North Fork of the Stillaguamish River, and other surface water supplies in the basin, present a mostly untapped resource.

TABLE 5-4. Low-flow frequency.

Discharge station	Recurrence interval (years)	7-day low-flow (cfs)	30-day low-flow (cfs)
North Fork near Darrington	5	45	56
	10	38	46
	20	33	38
South Fork near Granite Falls	5	110	140
	10	94	112
	20	82	94
South Fork near Arlington	5	154	204
	10	130	163
	20	113	135

Runoff is usually quite high, but varies widely during the winter and early spring, depending on temperature and precipitation. Runoff during summer and early fall, largely sustained by ground water contributions, is usually quite low but increases temporarily when supplemented by rainfall.

Seven-day and 30-day flows that may be expected to occur at the discharge stations indicated for recurrence intervals of 5, 10, and 20 years are shown in table 5-4.

Dams and Impoundments. There are no dams or reservoirs in the Stillaguamish Basin.

Lakes. The surface area of lakes and glaciers in the basin provides a comparative indication of the amount of stored water. The few lakes in the basin total about 2,600 acres, or 4.1 square miles, of surface area. Cavanaugh Lake in the headwaters of Pilchuck Creek (844 acres), Lake Goodwin (547 acres), Lake Shoecraft (137 acres), and Martha Lake (58 acres) are the largest lakes in the basin and comprise most of the total acreage. Glaciers in the basin have a total surface area of about 320 acres.

Quality

The source of the Stillaguamish River and the major portion of its watershed lie in Mount Baker National Forest, where land use is restricted primarily to recreation, fish, wildlife, and lumbering. The water quality of the river in this area is excellent for all uses, except when flow conditions produce intolerable amounts of turbidity and insoluble iron. Water quality characteristics as indicated by chemical, bacteriological, and physical analyses of water samples collected from the water quality stations are listed in Table 5-5.

Physical. Maximum stream temperatures on the North and South Forks are relatively low, usually less than 18°C (64°F) during the warmest months. Below Arlington, however, the Stillaguamish River gets somewhat warmer. A maximum temperature was recorded on the main stem near Silvana of 22.8°C (73° F).

The Stillaguamish River and its tributaries are usually turbid. The average range is 15 to 45 JTU on the North Fork, South Fork, and the main stem stream. Turbidity on the entire system ranges from 0.0 to 400 JTU. Color values are also high, attaining a maximum of 45 units on the main stem and 30 units on each fork.

Streamborne sediment in the Basin is low. Although precipitation in the upper part of the Basin is quite high, a dense cover vegetation retards erosion. At times, however, sediment from clay slides has been particularly detrimental to anadromous fish propagation and sport harvests. During low-flow, most streams in the upper drainages are nearly sediment-free.

Chemical. The chemical quality of the Stillaguamish River and its two forks is excellent. The water is soft, low in dissolved solids, and high in dissolved oxygen concentrations. (See table 5-5.) Calcium and magnesium ion concentrations, water hardness indicators, rarely exceed 22 mg/l The variation in the ratio of hardness ions found in these waters is directly related to flow; the lowest values of magnesium are found during periods of minimum flow. Changes in the magnesium ion ratios produce a complementary change in the calcium ion concentration. The sodium-potassium ion ratio remains fairly constant throughout the year. Average dissolved oxygen concentrations are high, ranging from 11.1 mg/l on the main stem to 11.7 mg/l on the South Fork.

Bacteriological. The bacteriological quality of the waters of the Stillaguamish River and its two forks is also excellent. During the period of record, 82 percent of the samples taken revealed less than 240 coliform organisms per 100 ml. This value compares favorably with controlled watersheds in the study area. High coliform values occasionally occur below points of heavy population density, with maximum MPN values ranging from 930 on the North Fork to 4,600 on the South Fork. On the main stem near Silvana, the maximum coliform density observed was 1,500 MPN.

GROUND WATER

Ground water sources supply at present, and are expected to supply in the future, more than 90 percent of all water used in the basin. Tests of ground water quality and estimates of reserves indicate that ground water sources will be capable of meeting anticipated requirements.

Quantity Available

Productive gravel and sand aquifers occur throughout sediments that occupy about 150 square miles in the central and upper valleys of the North and South Forks. In addition, important aquifers are found in coarse sedimentary zones, which cover a roughly equal area in the lowlands, and in deposits of alluvium, consisting mostly of sand, silt, clay, and peat on the flood plain and delta of the Stillaguamish River.

Estimates of annual recharge are not presently available for the central and upper valley of the North and South Forks. However, lowland aquifers, recharged almost completely by precipitation, receive an estimated average of about 40,000 acre-feet of recharge annually. Not all of this recharge can be captured by wells because most of the ground water is discharged into the river and its tributaries or into Port Susan through submarine springs. However, assuming only a 50 percent reclamation, ground water sources appear able to supply present and anticipated needs.

Quality

Ground water in the Basin is generally of good quality. The quantity of dissolved solids is usually less than 200 ppm and rarely exceeds 300 ppm. Water hardness ranges from 60 to 120 ppm; and silica content is usually between 20 and 40 ppm. Ground water quality data are presented in Table 5-6.

TABLE 5-5. Surface water quality.

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (μmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
		mg/l												mg/l									mg/l		mg/l		
STILLAGUAMISH RIVER NEAR GRANITE FALLS — JULY 1959 THROUGH 1966																											
Maximum	4,850	42	8.0	2.1	2.0	0.9	34	0	4.0	1.5	0.5	0.7	64	0.11	—	7.8	4.30	0.03	7.4	30	150	17.7	13.8	123	29	2	4,600
Mean	—	27	4.7	0.9	1.1	0.3	18	0	2.4	0.7	0.1	0.3	38	0.02	—	4.9	0.80	0.01	—	—	—	8.8	11.7	102	15	0	182
Minimum	153	15	2.5	0.1	0.6	0.0	11	0	1.2	0.0	0.0	0.0	22	0.00	—	2.8	0.03	0.00	6.1	5	0	1.0	8.9	93	9	0	0
Number	29	36	36	36	36	36	36	23	36	36	36	36	36	33	—	36	32	11	36	36	15	37	36	36	36	36	37
STILLAGUAMISH RIVER NEAR ARLINGTON — NOVEMBER 1961 THROUGH 1966																											
Maximum	5,070	55	10.0	2.8	2.9	0.9	44	0	3.6	2.5	0.2	1.0	80	0.04	—	9.1	2.80	0.02	7.6	30	136	17.6	13.8	141	34	1	930
Mean	—	36	5.9	1.6	1.7	0.5	26	0	2.7	1.2	0.1	0.6	51	0.02	—	6.2	0.53	0.01	—	—	—	9.2	11.6	103	21	0	182
Minimum	400	22	3.0	0.9	1.0	0.2	14	0	1.6	0.5	0.0	0.1	29	0.00	—	3.5	0.10	0.00	6.7	0	5	2.3	9.3	91	12	0	0
Number	11	18	18	18	18	18	18	18	18	18	18	18	18	15	—	18	15	8	18	18	14	19	19	19	18	18	19
STILLAGUAMISH RIVER NEAR SILVANA — JULY 1954 THROUGH 1966																											
Maximum	—	58	10.0	3.5	3.3	1.1	48	0	4.4	2.8	0.3	2.0	98	0.10	—	11.0	5.20	0.03	7.6	45	400	22.8	14.3	127	39	4	1,500
Mean	—	37	6.0	1.6	1.7	0.5	26	0	3.0	1.3	0.1	0.6	53	0.02	—	6.6	0.80	0.01	—	—	—	9.9	11.1	100	22	1	204
Minimum	—	17	3.0	0.5	0.8	0.0	13	0	0.9	0.0	0.0	0.0	26	0.00	—	3.2	0.05	0.00	5.9	0	0	1.8	4.8	40	11	0	0
Number	—	83	83	83	83	83	83	33	83	83	82	83	83	72	—	83	72	12	83	83	44	87	87	87	83	83	87

TABLE 5-6. Ground water quality.

Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids[b]	Hardness ($CaCO_3$)	Specific conductance (μmho)	pH
				(mg/l)											
U. S. Government (USFS)	30/8-16	3/16/60		19.0		20	5.3	5.8	1.3	0.1		105	72	167	8.1
City of Arlington	31/5-2L1	4/27/61	48	8.5	0.08	9	3.5	2.2	0.7	0.7	0.00	58	37	86	7.2
Peter Henning	31/5-7G1	10/5/60	49	39.0	1.80	39	19.0	47.0					178	583	7.2
A. J. Strotz	31/5-7H1	9/2/44		28.0	9.40[d]	17	14.0	5.5	2.3	4.5		131	100	217	6.7
A. C. Ladd	32/4-28B1	10/12/60	53	30.0	0.04	18	11.0	8.7	1.1	6.0	0.09	152	92	230	7.0
Stanwood Water Co. (Well 4)	32/4-29B2	10/5/60	48	33.0	0.13	22	13.0	16.0	6.4	0.6	0.96	180	106	276	8.2
G. M. Eliot	32/6-18H1	10/5/60	49	24.0	0.83	40	17.0	66.0	6.4	6.6	1.60	357	169	561	7.7

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

As in any other area, the prime factors determining future water requirements in the Stillaguamish basin are population and industrial growth, including increases in agricultural production. As these factors increase, withdrawal and use of water also increase, but at a slightly greater rate.

PROJECTED POPULATION GROWTH

The 1967 Basin population of 18,300 is forecast to increase 60 percent to 30,200 by 1980, 157 percent to 48,500 by 2000, and 310 percent to 77,800 by 2020. Figure 5-2 illustrates predicted Basin populations in the various areas. The most rapid growth is expected to occur in the Stanwood area in accordance with forecast industrial expansion.

PROJECTED INDUSTRIAL GROWTH

Production growth of the major water using industries, in terms of value added to the community, is expected to increase by 200 percent between the present and the year 2020, as shown in Figure 5-3. Agricultural activities are expected to increase moderately through the year 2000 and then show a relatively sharp increase to meet the demands of adjacent metropolitan centers. The increase in production of agricultural products is also expected to cause a substantial increase in the growth of food processing industries.

The production of stone, clay, and glass is estimated to increase at a rate similar to that of the food production industries.

The increase in pulp and paper production in nearby basins is expected to be accompanied by a steady decrease in lumbering as timber usage shifts from lumber production to pulp production.

PROJECTED WATER REQUIREMENTS

Total water requirements in the Basin are predicted to reach 16.6 mgd by the year 2020, representing an increase of nearly 800 percent from 1965 usage. Figure 5-4 illustrates municipal and industrial water requirements by service area. Tables 5-7, 5-8, and 5-9 detail water use requirements for the years 1980, 2000, and 2020. Table 5-10 summarizes projected water needs in the Basin.

Municipal

Water requirement projections indicate that municipal users will need about 2.4 mgd (51 percent of the total usage) by 1980, 5.0 mgd (54 percent) by 2000, and 9.8 mgd (57 percent) by 2020. Per capita

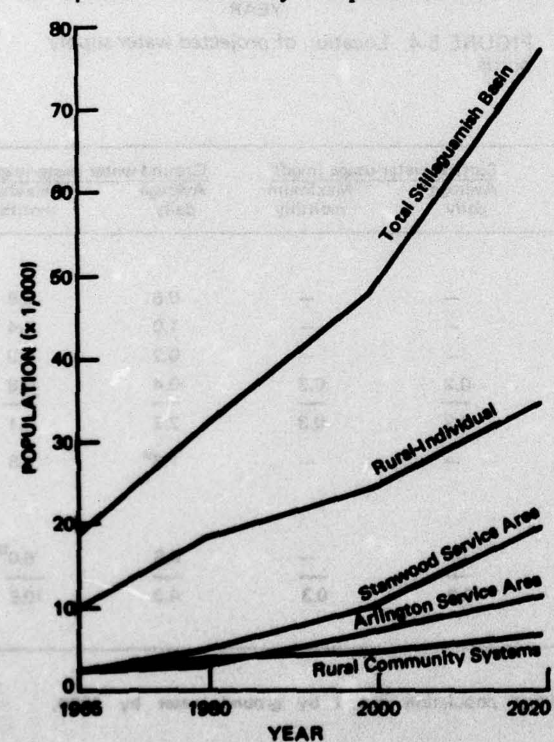


FIGURE 5-2. Projected population growth.

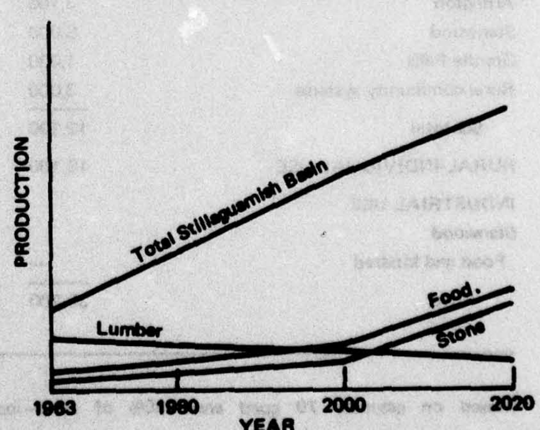


FIGURE 5-3. Relative production growth for major water-using industries.

municipal water use is expected to increase from about 147 gallons per day in 1965, to 198 gpd in 1980, to 206 gpd in 2000, and to 228 gpd in 2020. A percentage increase in municipal water requirements relative to total water usage is largely accounted for by increased per capita usage and a slight population shift to the more urbanized areas.

Industrial

Industrial water requirements, presently 0.6 mgd, are expected to increase to 0.8 mgd by 1980, to 1.7 mgd by 2000, and to 3.0 mgd by 2020. Throughout the period, industrial demand accounts for about 18 percent of the total projected water use in the basin.

Rural-Individual

Rural-individual water requirements are expected to increase to about 1.3 mgd by 1980, to 2.2 mgd by 2000, and to about 3.8 mgd by 2020. But, in keeping with the increased trend toward urbanization, this demand will represent a steadily decreasing percentage of total water needs in the basin.

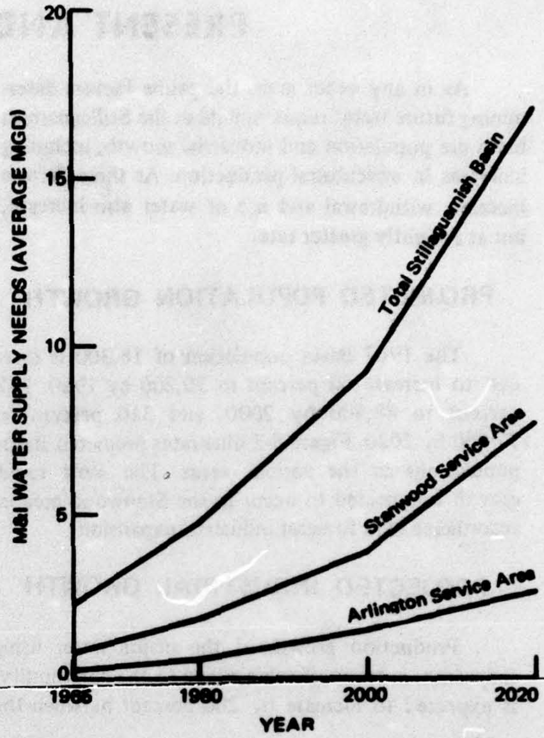


FIGURE 5-4. Location of projected water supply needs.

TABLE 5-7. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Arlington	3,100	–	–	0.6	0.8
Stanwood	5,000	–	–	1.0	1.4
Granite Falls	1,000	–	–	0.2	0.3
Rural community systems	3,000	0.2	0.3	0.4	0.6
Subtotal	12,100	0.2	0.3	2.2	3.1
RURAL-INDIVIDUAL USE	18,100	–	–	1.3[a]	1.8
INDUSTRIAL USE					
Stanwood					
Food and kindred	–	–	–	0.8	6.0[b]
Total	30,200	0.2	0.3	4.3	10.8

[a] Based on assumed 70 gpcd and 100% of rural-individual population served by ground water by 1980.

[b] Based on present (1965) ratio of ADU to MMU.

TABLE 5-8. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
MUNICIPAL USE					
Arlington	7,300	—	—	1.5	2.1
Stanwood	10,000	—	—	2.1	2.9
Granite Falls	2,000	—	—	0.4	0.6
Rural community systems	5,000	0.3	0.4	0.7	1.0
Subtotal	24,300	0.3	0.4	4.7	6.6
RURAL-INDIVIDUAL USE	24,200	—	—	2.2[a]	3.0
INDUSTRIAL USE					
Stanwood					
Food and kindred	—	—	—	1.7	12.0[b]
Total[c]	48,500	0.3	0.4	8.6	21.6

[a]Based on assumed 90 gpcd and 100% of rural individual population served by ground water by 1980.

[b]Based on present (1965) ratio of ADU to MMU.

[c]Figures are rounded.

TABLE 5-9. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
MUNICIPAL USE					
Arlington	11,800	—	—	2.7	3.8
Stanwood	20,000	—	—	4.6	6.5
Granite Falls	4,000	—	—	0.9	1.3
Rural community systems	7,000	0.5	0.7	1.1	1.5
Subtotal	42,800	0.5	0.7	9.3	13.1
RURAL-INDIVIDUAL USE	35,000	—	—	3.8[a]	5.4
INDUSTRIAL USE					
Stanwood					
Food and kindred	—	—	—	3.0	22.0[b]
Total[c]	77,800	0.5	0.7	16.1	40.5

[a]Based on assumed 110 gpcd and 100% of rural individual population served by ground water by 1980.

[b]Based on present (1965) ratio of ADU to MMU.

[c]Figures are rounded.

TABLE 5-10. Summary of projected water needs.

System		Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)		Total usage (mgd)	
			Average daily	Maximum monthly	Average daily	Maximum monthly	Average daily	Maximum monthly
Municipal	1965	6,800	0.1	0.1	0.9	1.5	1.0	1.6
	1980	12,100	0.2	0.3	2.2	3.1	2.4	3.4
	2000	24,300	0.3	0.4	4.7	6.6	5.0	7.0
	2020	42,800	0.5	0.7	9.3	13.1	9.8	13.8
Industrial	1965	—	—	—	0.6	4.0	0.6	4.0
	1980	—	—	—	0.8	6.0	0.8	6.0
	2000	—	—	—	1.7	12.0	1.7	12.0
	2020	—	—	—	3.0	22.0	3.0	22.0
Rural–Individual	1965	12,100	0.1	0.1	0.6	0.9	0.7	1.0
	1980	18,100	—	—	1.3	1.8	1.3	1.8
	2000	24,200	—	—	2.2	3.0	2.2	3.0
	2020	35,000	—	—	3.8	5.4	3.8	5.4
Totals	1965	18,900	0.2	0.2	2.1	6.4	2.3	6.6
	1980	30,200	0.4	0.6	4.3	10.9	4.5	11.2
	2000	48,500	0.6	0.8	8.6	21.6	8.9	22.0
	2020	77,800	1.0	1.4	16.1	40.5	17.1	41.2

Note: All usage figures are rounded to one decimal place.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 13 mgd by the year 2020. This is an increase of approximately 11 mgd over the 1965 average use. Optimum or peak water requirements will be almost four times this average or near 50 mgd. Tables 2-10 or 2-11, the Area Plans, summarize the Basin's annual average and optimum requirement in relation to the remainder of the Area. Table 5-11, M & I Water Supply Capital Improvements, reviews the needs of the major water systems and/or users in the Basin.

The public water systems of Stanwood and Arlington are expected to supply about 83 percent of the total projected municipal and industrial water requirements for the entire basin by the year 2020. Rural supply systems, are expected to provide about 4.6 mgd to about 35,000 persons.

This amount is within the potential of the basin without conflict over withdrawals for water supplies. No need for water from outside the basin is apparent. Urban growth is not anticipated to bring about sufficient population density to make a county-service or regional water supply and transmission system feasible.

The major water users will be centered around the few urbanized areas supplied with municipal and industrial water from presently developed and expanded ground water sources near these urban centers. Most wells in this area are less than 150 feet deep and are, therefore, low in capital cost.

A plentiful source of surface water is also available to meet needs. Surface water would require treatment and chlorination, therefore limiting its use as a supply source due to the increased cost.

BASIN PLANS

The Selected Basin Plan recommended is to continue the use and development of present ground water supplies to the year 2020. All existing equipment and sources will continue to be used, but

projected source development will be from conventional vertical wells. Table 5-12 defines the plan and includes supply and transmission, treatment, pumping, chemical, and annual income as projected by the M&I Water Supply Technical Committee. Table 2-10 includes the storage and distribution costs for the basin.

The Alternative Basin Plan was determined on the basis of using existing water supplies with future supplies to be developed from surface sources.

To develop surface supplies in this Basin as an alternative to ground water supplies is considerably more expensive and apparently not within the present annual income abilities.

Table 5-13 describes the plan, Table 2-11 summarizes costs. Costs for this Alternative are appreciably higher, $6 million, than for the Selected Basin Plan. Storage and distribution costs are shown in Table 2-11.

Stanwood will not need additional supply capacity until the year 1975. At this time, a new well to meet peak demands will be required. One additional well after the year 2000 will provide all future needs up to the year 2020.

The water supply situation for the City of Arlington is similar to that of Stanwood except that the industrial demand is smaller. Two existing wells now produce a total of 2.3 mgd. A 2.5 mgd well development by 1975 to meet peaks and a 3.0 mgd development in 1990 will supply all water requirements.

Surface and ground water supplies can be economically utilized by rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Table 5-10, Summary of Projected Water Needs, shows the low level of need to 2020 from all sources. On this basis, a ground-water source is recommended as the least expensive alternative, and would still be adequate to satisfy the projected needs.

TABLE 5-11. M & I Water Supply—Capital Improvements
BASIN: Stillaguamish

	M. G. D.			
	Present		Future	
	1966	1966-1980	1980-2000	2000-2020
Population Served	2,190	3,100	7,300	11,800
ARLINGTON				
Optimum	1.4	2.0	4.8	7.8
Capital Improvements	0	0	2.5	3.0
Population Served	2,000	5,000	10,000	20,000
STANWOOD				
Optimum	5.3	9.3	18.6	35.2
Capital Improvements	0.6	4.0	9.3	16.6
Population Served	600	1,000	2,000	4,000
GRANITE FALLS				
Optimum	0.4	0.7	1.3	2.6
Capital Improvements	0.3	0.3	0.6	1.3
Population Served	2,010	3,000	5,000	7,000
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	1.3	1.9	3.3	4.6
Capital Improvements	1.1	0.6	1.4	1.3
Population Served	6,800	12,100	24,300	42,800
TOTAL				
Capital Improvements	2.0	5	14	22

NOTE: Figures are rounded.

TABLE 5-12. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Stillaguamish Basin

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D: Supply	OPTIMUM CAPACITY M G D: Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b]: Supply & Transm.	AMORTIZED CAPITAL COST[b]: Treat-ment	AMORTIZED CAPITAL COST[b]: Iron Removal	MAINTENANCE AND OPER.: Pumping Power	MAINTENANCE AND OPER.: Chem.	Total Annual Income
ARLINGTON												
Present	GW	Local GW Development	Exist.	0.4	2.3	2.3				4		42
1980	GW	Local GW Development	1970	1	2.6	2.6	150			6		117
2000	GW	Local GW Development	1980	2	3.0	3.0	180			16		234
2020		No Future Requirements		3						29		350
ARLINGTON SELECTED PLAN TOTAL				7.8	7.8	7.8	$ 330					
STANWOOD												
Present	GW	Local GW Development	Exist.	1	4.7	4.7				11		117
1980	GW	Local Development	1970		0.6	0.6	36					
1980	GW	Local GW Development	1975	2	4.0	4.0	240			19		234
2000	GW	Local GW Development	1985-2000	4	9.3	9.3	558			40		467
2020	GW	Local GW Development	2005-2015	8	16.6	16.6	996			80		434
STANDWOOD SELECTED PLAN TOTAL					35.2	35.2	$1,830					
GRANITE FALLS												
Present	GW	Local GW Development	Exist.	0.1	0.1	0.1				1		12
1980	GW	Local GW Development	1970	0.2	0.6	0.6	36			2		23
2000	GW	Local GW Development	1990	0.4	0.6	0.6	36			4		47
2020	GW	Local GW Development	2010	1	1.3	1.3	78			10		117
GRANITE FALLS SELECTED PLAN TOTAL					2.6	2.6	$ 150					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local GW & SW Development	Exist.	0.2	0.2	0.2				1		12
1980	GW	Local GW & SW Development	1970		1.1	1.1	66					
1980	GW	Local GW & SW Development	1975	0.6	0.6	0.6	36			4		47
2000	GW	Local GW & SW Development	1990	1	1.4	1.4	84			7		117
2020	GW	Development	2010	2	1.3	1.3	78			12		117
SMALL & RURAL COMMUNITY SYSTEMS SELECTED PLAN TOTAL					4.6	4.6	$ 264					
SELECTED BASIN PLAN TOTAL					50.2	50.2	$ 2,574					

[a] Initial development.

[b]Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c]All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.6 gpm per service connection plus the maximum industrial monthly demands.

TABLE 5-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Stillaguamish Basin

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D[d] Supply	OPTIMUM CAPACITY M G D[d] Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b] Supply & Transm.	Treat-ment	Iron Removal	MAINTENANCE AND OPER. Pumping Power	Chem.	Total Annual Income
ARLINGTON												
Present	GW	Local Ground Water	Exist.	0.4	2.3	2.3				4		47
1980	SW	Intake & Treatment—Stillaguamish River	1975	1	5	5	$ 650			6		117
2000	SW	Intake & Treatment—Stillaguamish River	1990	2	3	3	390			16		234
2020	SW	No Future Needs (Wells on Standby)		3						28		350
ARLINGTON ALTERNATIVE PLAN TOTAL					8	8	$1,040					
STANWOOD												
Present	GW	Local GW Development	Exist.	1	4.7	4.7				11		117
Present	GW	Local GW Development, ADD: 0.6mgd	1970		0.6	0.6	36					
1980	SW	[a] Stillaguamish River (Intake & Treatment)	1975	2	9	4	820	$ 675		19	4	234
2000	SW	Stillaguamish River (Intake & Treatment)	1985	4	9	9	1,209	675		40	4	467
2020	SW	Wells on Standby After 1975 (Intake at RM 8.1)	2005	8	17	17	2,158	1,270		80	9	934
					36	36	3,923	2,620				
STANWOOD ALTERNATIVE PLAN TOTAL							$6,543					
GRANITE FALLS												
Present	GW	Local Ground Water Development	Exist.	0.1	0.1	0.1				1		12
1980	SW	[a] Stillaguamish River (Intake & Treatment)	1975	0.2	1.0	1.0	130	75		2		23
2000	SW	Stillaguamish River (Intake & Treatment)	1990	0.4	1.6	1.6	195	110		4		47
2020	SW	No Future Needs		1						10		117
					2.6	2.6	$ 325	$185				
GRANITE FALLS ALTERNATIVE PLAN TOTAL								$510				
SMALL & RURAL COMMUNITY SYSTEMS (Same as Selected Plan)					4.6	4.6	$ 264					
ALTERNATIVE BASIN PLAN TOTAL								$8,367				

[a] Initial development.

[b] Does not include storage and distribution costs; See Area Means to Satisfy Needs section.

[c] All figures are rounded.

[d] Not a design mgd—optimum capacity represents the total system ability to deliver 1.6 gpm per service connection plus the maximum industrial monthly demands.

FINANCE

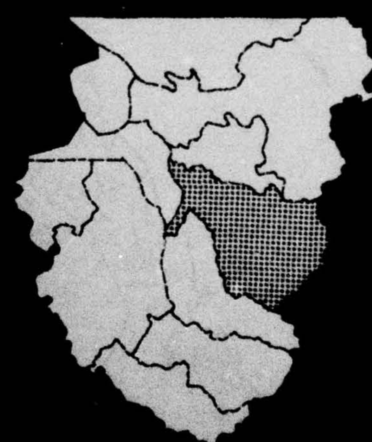
Annual income as taken from Table 2-10 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

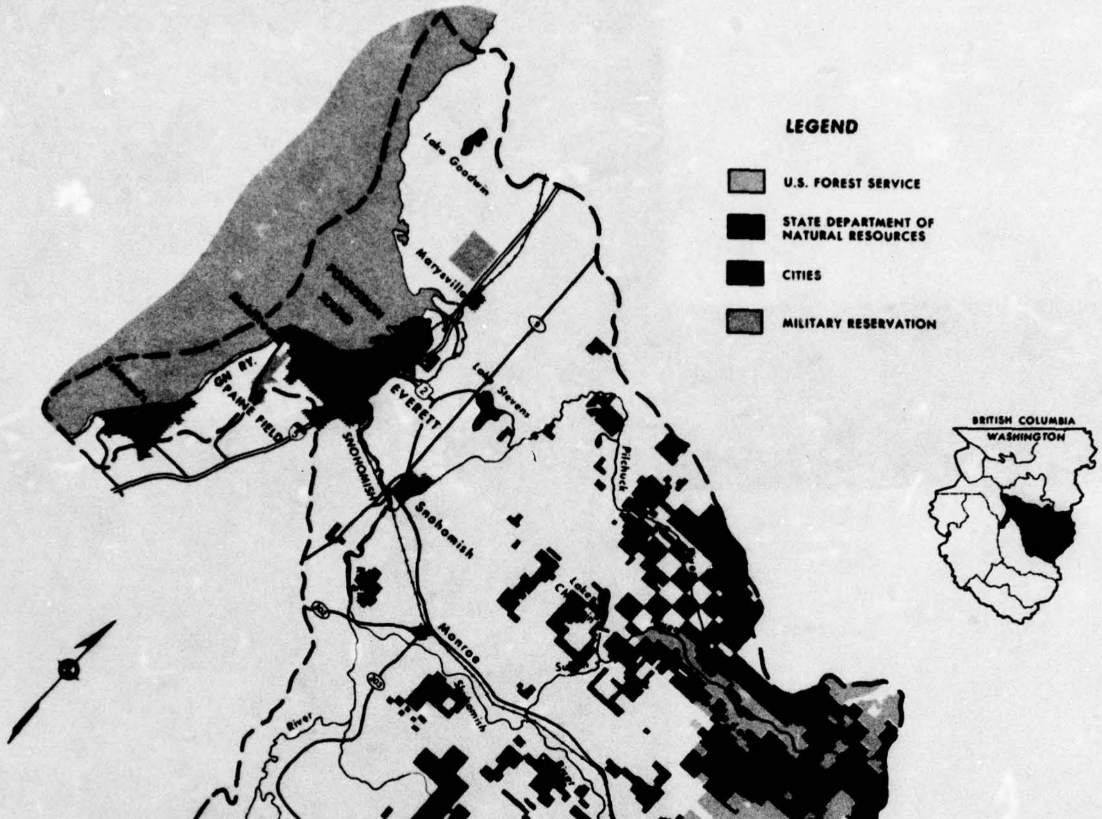
The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the selected and alternative plans.

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that by 1980 the Stillaguamish Basin will be unable to bond for the required water supply development, and future construction would involve excessive financial burden in relation to the Basin's economic resources and require an increase in water rates.

Year	Bond Service Available (x 1,000)	Annual Amortized Cost (x 1,000) Selected Plan	Alternative Plan
1965	42	$ 24	$ 24
1980	94	80	134
2000	185	177	237
2020	327	264	342

Snohomish Basin





SNOHOMISH BASIN

Figure 6—1 Land Ownership

SNOHOMISH BASIN

INTRODUCTION

The Snohomish Basin, Figure 6-1, bounded on the east by the ridge line of the Cascade Mountain Range and on the west by Puget Sound, is located between the Stillaguamish and Cedar-Green Basins in the central portion of the Puget Sound Area. The basin, occupying about 1,978 square miles in northeastern King and southern Snohomish Counties, encompasses the urban-industrial center of Everett, agricultural areas of Snohomish and Monroe, and small towns and cities along the Snoqualmie River.

A rapid increase in population and industry in Everett and vicinity is projected as part of the growth of the Seattle-Everett industrial area, and the demand for industrial and municipal water will increase commensurate with this growth. Estimates based on the projected growth indicate a three-fold increase in water use from the present 165 million gallons per day to 540 mgd. by 2020. While the present supply of surface and ground water is adequate, additional water storage facilities, some of which are already in the development stage, will be required to stabilize the water supply throughout the year.

GEOGRAPHY

A large part of the Snohomish basin is mountainous terrain (photo 6-1), rugged foothills, valleys, and streams; the remaining portion consists of rolling hills and flatland, much of which is fertile agricultural land. The eastern portion of the basin is a heavily forested, mountainous region, with such outstanding physical features as Snoqualmie Falls, Snoqualmie Mountain, and Mount Daniel. The topography of the western portion of the basin is characterized by rolling hills, which taper off into sea level tidal flats at the mouth of the Snohomish river.

Much of the original lowland forest cover of Snohomish County has been removed by logging and clearing, but the mountainous eastern section is still covered by large stands of virgin forest. Despite heavy forest cutting, there is still a rich resource of timber for lumber production and paper manufacturing.

The Skykomish and Snoqualmie Rivers, which join near the town of Monroe to form the Snohomish River, are the most important river systems in the basin. The Skykomish river and its major tributaries, the North and South Forks and the Sultan River, form the largest river system in the basin and drain nearly 850 square miles in the northern portion of the basin. The Snoqualmie River and its major tributaries, the North, Middle, and South Forks and the Tolt River drain approximately 690 square miles in the southern portion of the basin. The remainder of the basin west of Monroe drains directly into the Snohomish River through a number of small tributary rivers and streams.

CLIMATE

Because of the large variation in elevation, the basin exhibits marked differences in climate. Mean temperatures vary from 10°C (50°F) at the lower elevations to 6.2°C (43°F) in the mountains, and maximum temperatures of over 37.8°C (100°F) at the lower elevations and a minimum of -8.4°C (-18°F) at Snoqualmie Pass have been recorded. Mean annual precipitation varies from about 180 inches in the headwaters of the Skykomish and Snoqualmie Rivers to about 30 inches near the mouth of the Snohomish River. Mean annual snowfall is generally less than 10 inches in the lowlands. However, it reaches 458 inches at Stampede Pass. Approximately 75 percent of the yearly precipitation falls during October through March. The growing season varies from 165 days in southern Snohomish County to 240 days in northern King County.

POPULATION

The Snohomish Basin, which in 1965 had an estimated population of 201,300, includes the northern portions of the Pacific Northwest's largest metropolitan area—the Seattle-Everett urban area. In 1965 the Everett urban area was estimated to have a population of about 52,000 persons. Other urban areas of the Snohomish Basin are the relatively small towns of Snohomish, Monroe, Snoqualmie, North Bend, Sultan, Snoqualmie Falls, Carnation, Duvall, Gold Bar, Startup, and Index.

PHOTO 6-1. The Alpine Lakes area in Snoqualmie National Forest is typical of mountainous terrain in the eastern part of the basin.

The establishment by The Boeing Company of the large Model 747 airplane manufacturing facility near Everett has contributed, and will continue to contribute, to the increasing population in the Everett region. Population expansion in the Seattle area, with an increasing shift of residential developments east of Lake Washington into the basin, will add to the population of the smaller towns.

ECONOMY

The economy of the basin is dominated by lumber and paper industries, and, to an increasing degree, by airplane manufacturing (The Boeing Company). The various industries are concentrated in and around Everett, and are a part of the vast Seattle-Everett urban-industrial complex. Logging and some other related industries are spread along the major rivers in the mountainous areas. The flatlands surrounding the lower Snohomish and Snoqualmie Rivers are devoted to agricultural products, primarily dairying and associated activities. Other industries in the basin include boat building, food processing, and a multitude of smaller manufacturing firms.

As a result of the industrial and population growth of the area, the economy is certain to benefit from the development of many smaller industrial firms and the many supply and service businesses required.

LAND USE

Forested areas, mostly in the northern and eastern portions of the basin, comprise more than 80 percent of the land area in the Snohomish basin. Cropland and rangeland, largely concentrated in bottomlands of the Snohomish and Snoqualmie Rivers, account for slightly more than 8 percent of the total acreage. Urban developments concentrated in and around Everett occupy less than two percent of the total land area. Table 6-1 shows the various uses of land in the Snohomish basin.

TABLE 6-1. *General land use.*

Use	Acres
Forestland	1 055,000
Cropland	72,000
Rangeland	2,000
Other land (high, barren)	29,000
Urban buildup	36,000
Inland water	24,000
Salt water	49,000
Total*	1,218,000

*Source: Appendix III, Hydrology.

PRESENT STATUS

WATER USE

An average of more than 164 million gallons of fresh water is supplied daily to present municipal, industrial, and rural-individual users. Of this, 81 percent (134 mgd) is used in the pulp and paper industries. Approximately 98 percent of the total water is supplied from surface sources; the remaining water is supplied by various municipal and private wells. Table 6-2 lists fresh water consumption statistics for the Snohomish basin.

TABLE 6-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Maximum daily	Ground water usage (mgd) Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Everett	126,500	20.10	23.10	33.75	—	—	—
Alderwood Water District	(66,000)	(5.60)	(8.50)	(14.00)	—	—	—
Monroe	(4,500)	(0.35)	(0.40)	(0.55)	—	—	—
Marysville	4,500	—	—	—	0.75	1.12	1.50
Snohomish	4,000	(1.50)	(3.00)	(4.25)	—	—	—
Edmonds[a]	10,000	0.58	0.87	1.16	—	—	—
Snoqualmie	2,700	—	—	—	0.16	0.31	0.47
North Bend	2,000	0.20	0.22	0.25	—	—	—
Carnation	1,250	—	—	—	0.12	0.25	0.36
Fall City Water Company	1,200	—	—	—	0.10	0.20	0.29
Duvall[b]	(525)	(0.03)	(0.06)	(0.10)	—	—	—
Skykomish Water District	500	—	—	—	0.10	0.20	0.30
Other rural community systems	2,110	0.28	0.39	0.44	0.10	0.21	0.36
Subtotal	154,760	22.69	27.58	39.95	1.33	2.29	3.27
RURAL-INDIVIDUAL USE	35,940	0.20[c]	0.28	0.40	1.78	2.50	3.50
INDUSTRIAL USE							
Municipally supplied:							
Everett							
Paper and allied		102.00	106.00	112.00	—	—	—
Lumber and wood		2.15	2.35	2.63	—	—	—
Chemicals, metals, oils		0.05	0.07	0.08	—	—	—
Stone, clay, glass		0.25	0.25	0.30	—	—	—
Snohomish							
Food and kindred		1.75	1.90	2.10	—	—	—
Self-supplied:							
Paper and allied		32.00	33.30	36.20	—	—	—
Stone, clay, glass		0.12	0.12	0.12	0.36	0.72	1.08
Subtotal		138.30	144.00	152.40	0.36	0.72	1.08
Total[d]	190.700	161.21	171.90	193.00	3.50	5.50	7.90

[a] Edmonds also supplied by Alderwood Water District and Olympic View Water District.

[b] Duvall served by Seattle.

[c] Based on assumed 55 gpcd.

[d] Figures are rounded.

• Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

Municipal

Total average daily municipal water use from both surface and ground sources is 24.02 mgd, about 14 percent of all water used in the basin.

Average municipal water use within the city limits of Everett, based on data for the 3-year period 1960 through 1962, and the 7-month period March through September 1966, is approximately 16 mgd. In 1966, total use outside the Everett city limits averaged 5.6 mgd, with the Alderwood Water District using most of the water. The usage figures include water distributed for public, domestic, and commercial use as well as water distributed for use by the type of small industries common to a municipality the size of Everett. 16.6 percent of the water from the Everett system goes to municipal use.

Per capita water use varies from city to city within the basin, but per capita water usage averages 150 gpd, based on the total amount of municipal water used and the total municipal population served.

The city of Everett sells water within the city on a flat rate basis rather than a metered usage figure. This, in large part, accounts for the rather high overall per capita use of 320 gpd within the city. Everett also supplies water to the Alderwood Water District, a completely metered system. Per capita usage within this area is markedly lower, about 85 gpd. Municipal per capita water use for the remaining areas is about 100 gpd.

Demand profiles for the city of Everett are shown in figure 6-2. During the month of August, municipal consumption reaches a peak of 110 percent of the average annual municipal consumption. This is much lower than summer consumption in the Seattle and Tacoma areas. The industrial water use profile shows less variation than the municipal profile, mainly because of the relatively constant use of water by the pulp and paper industry. The total system profile, ranging between 95 and 105 percent of the average annual, reflects the leveling effect of the industrial segment.

Industrial

Industrial consumers use more than 85 percent of all water required in the basin. Pulp and paper plants located in the Everett area are by far the largest water users in the basin. Collectively, they consume about 81 percent (134 mgd) of the total water supplied in the basin. Table 6-3 presents a breakdown of water use by the various pulp and paper plants.

Rural-Individual

Rural-individual use of fresh water, supplied mainly by private and community wells, accounts for slightly less than 2 mgd, approximately 2.2 percent of of the total basin fresh water use. Rural per capita use of water is approximately 55 gallons per day.

WATER SUPPLIES

About 70 water systems in the Snohomish basin serve a total of about 125,000 people, or about 70 percent of the 1965 basin population. The systems vary widely in size, with more than 90 percent serving fewer than 200 people each.

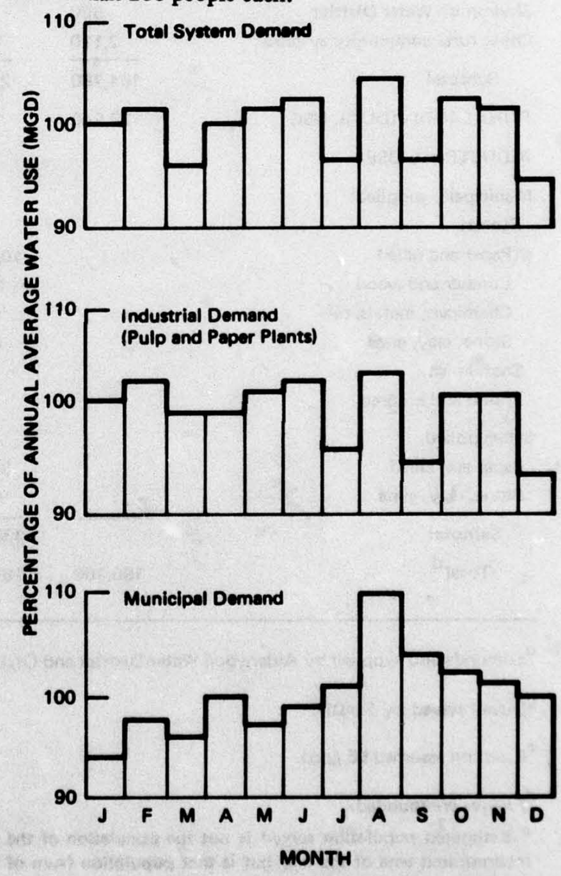


FIGURE 6-2. Everett water use profiles.

TABLE 6-3. Industrial water use.

Plant	Contract demand (city source)	Production capacity (tons/Day)	Average daily use (mgd)	Unit water use (gallons/ton)
Scott Paper Company (sulfite pulp)	67	828	55	66,500
Scott Paper Company (sulfite paper)		528	10	19,000
Weyerhaeuser Company (sulfite pulp)	28	304	27	88,700
Weyerhaeuser Company (sulfate pulp)		417	32[a]	76,800
Simpson Lee Company (paper)	12	180	10	35,800
Simpson Lee Company (sulfate pulp)		100		
Total	107			
Average Unit Use		2,357	134	57,000

[a]Self-supplied.

Present municipal, industrial, and domestic water use in the Snohomish basin averages about 164 mgd (254 cfs). Surface water supplies 161 mgd (252 cfs) of this total, and ground water, taken from municipal, community, and private wells, supplies the remaining 3 mgd.

Municipal

Everett uses surface water drawn from the Sultan River as its source of supply. Water is diverted from the Sultan River, flows by pipeline and tunnel to Lake Chaplain (photo 6-2), which serves as a sedimentation basin and storage reservoir, and is then delivered to Everett through four pipelines. The present peak capacity of Everett's water supply source and transmission facility is 170 mgd. The present storage capacity of Lake Chaplain is 4.35 billion gallons (13,300 acre-feet), and Everett and the Snohomish County PUD No. 1 have completed the first stage of a reservoir on the Sultan River which does provide 31,000 acre-feet of additional water storage capacity.

Everett supplies about 90 percent of the municipal water requirements of its urban area. The remainder is supplied by the separate facilities of several communities and water companies. Everett also provides water to Monroe and to the Alderwood Water District, which in turn supplies water to Mountlake Terrace, Brier, Lynnwood, and Edmonds.

Marysville delivers approximately 0.75 mgd. to an estimated 4,500 persons. The water comes from a spring and several wells, and is chlorinated before delivery.

PHOTO 6-2. Lake Chaplain stores water for municipal and industrial use in Everett.

Monroe receives treated water from Everett, but also has wells for standby and peaking purposes. The ground water is disinfected before distribution. The system provides approximately 0.35 mgd average daily use to an estimated 4,500 persons, including the Sky Meadows Water District and the Washington State Reformatory.

Snohomish obtains its water supply from the Pilchuck River. After disinfection, water is furnished to an estimated 4,000 people at an estimated average daily use of 0.50 mgd.

Snoqualmie, Carnation, Skykomish Water District's, serving an estimated total of 4,450 people, use ground water obtained from springs or wells, and do not provide treatment. Total average daily water use by these three towns is about 0.38 mgd.

North Bend, Gold Bar, Index Water District's obtain water supplies from surface sources, and serve approximately 2,630 people. North Bend and Gold Bar Water District disinfect their water; the town of Index does not treat its water supply at the present time. Total average daily use by these systems is about 0.45 mgd.

Duvall. obtains water from the Seattle water system, disinfects the water, and distributes it to about 525 people at an averrage rate of about 0.032 mgd.

Industrial

Scott Paper Company, Simpson Lee Paper Company, and the Weyerhaeuser Company sulfite mill obtain water from the city of Everett. They are supplied a combined total of 102 mgd, or 78.5 percent of the total water used in the basin. The Weyerhaeuser Company sulfate (Kraft process) pulp mill in Everett, presently obtains about 32 mgd of water from the Snohomish River and is the only major industrial water user in the basin with a private source of supply.

Rural-Individual

Based on 3.4 persons per household, an estimated 35,940 persons are supplied an average of 1.98 mgd by 9,700 rural-individual water systems. An estimated 90 percent of these systems utilize ground water, mainly from private and community wells.

WATER RIGHTS

Water rights in the Snohomish basin were summarized by the Washington State Department of Conservation (now Department of Water Resources) in 1962. This summary lists 716 applications for diversions totaling over 5,600 cfs in the entire basin. Temporary permits have been granted to 442 of these applicants in the amount of nearly 1,300 cfs. Three hundred and sixty-two certified or permanent water rights have been issued for approximately 600 cfs.

Water rights in the Skykomish River basin total 4,765 cfs. Applications account for 3,660 cfs of this amount, with temporary permits and certified water rights accounting for 678 and 426 cfs, respectively.

In the Snoqualmie River basin, water rights total 2,282 cfs. Applications account for 1,792 cfs of this amount, with temporary permits and certified or permanent water rights accounting for 394 and 95 cfs, respectively.

Table 6-4 lists a summary of surface and ground water rights, applications, permits and certificates for the Snohomish basin.

TABLE 6-4. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	449.1	37.3	70.0
Ground water	8.5	13.5	5.1
Total[a]	457.6	50.8	75.1

[a] About 580 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

SURFACE WATER

Quantity Available

Streams. The Snohomish River, formed by the junction of the Skykomish and Snoqualmie Rivers near the town of Monroe, is between 350 and 500 feet wide and is affected by tides for a distance of 18 of its 22 miles of length.

The Skykomish River, largest tributary of the Snohomish River, with a drainage area of 844 square miles, is formed by the junction of its North and South Forks near the town of Index. It flows westerly about 28 miles to its confluence with the Snoqualmie River.

The Snoqualmie River has a drainage area of 693 square miles. It is formed by the junction of the North, Middle, and South Forks near the town of North Bend, about four miles upstream from Snoqualmie Falls (photo 6-3). Below the falls, the river flows northwesterly about 36 miles to its confluence with the Skykomish River.

PHOTO 6-3. Snoqualmie Falls, which drops 268 feet, is nearly dry during low-flow periods when most of the water passes through power-generation turbines.

More than 20 stream discharge stations are currently operating in the Snohomish River basin. However, only four of these stations supply accurate information on total basin drainage. Two discharge stations, one on the Skykomish River at Gold Bar and one on the Sultan River near Startup, measure runoff from 535 square miles drained by the forks of the Skykomish River and from 74.5 square miles drained by the Sultan River. These stations provide runoff data for nearly 75 percent of the area drained by the Skykomish River system. A discharge station on the Snoqualmie River near Carnation, downstream from the junction of the Snoqualmie and Tolt Rivers, measures runoff from approximately 90 percent (603 square miles) of the area drained by the Snoqualmie River system. A discharge station near the mouth of the Snohomish River near the town of Snohomish measures runoff from the entire Snohomish basin. However, tidal fluctuations at this station make it impractical to compute flows of less than 10,000 cfs.

During the 37-year period 1928 through 1965, the annual flow of the Skykomish River at Gold Bar averaged 3,912 cfs. Measurements taken during the same period at the gaging station at Startup indicate a mean annual flow in the Sultan River of 797 cfs. Measurements from the Snoqualmie River near Carnation, also taken during the 37-year period 1928 through 1965, reflect a mean annual flow of 3,789 cfs. Although tidal fluctuations affected the accuracy of measurements, records from the Snohomish gaging station indicate a mean annual runoff from the total basin of 9,500 cfs.

The Snohomish River usually has two high water periods each year: one in the fall or winter coinciding with the time of maximum precipitation, and one in the spring during melt-off of the snowpack in the higher elevations. Low flows usually occur in August or September with a second low-flow period occurring in early spring.

Mean monthly flows at these stations for the period April 1, 1946, to March 31, 1964, were analyzed to predict low-flow levels that could be expected in any 5-, 10-, or 20-year interval. These low flows and intervals are presented in table 6-5.

Dams and Impoundments. Water resource development in the Snohomish River basin has been minimal in the past. The Puget Sound Power and Light Company has a run-of-the-river power plant

TABLE 6-5. Low-flow frequency.

Discharge station	Recurrence interval (years)	7-day low-flow (cfs)	30-day low-flow (cfs)
Snoqualmie River at	5	500	600
Carnation	10	450	510
	20	425	450
Skykomish River near	5	570	700
Gold Bar	10	490	580
	20	430	500
Sultan River near Startup	5	77	100
	10	64	80
	20	55	66

on the upper Snoqualmie River at Snoqualmie Falls. In 1963 the city of Seattle completed construction of a water supply storage facility on the South Fork of the Tolt River (photo 6-4), a tributary of the Snoqualmie River. The Sultan River, a tributary of the Skykomish River, is the source of supply for the city of Everett. In addition, some local flood control and navigation works are under way or have been completed in the lower basin.

Lakes The total amount of storage in lakes in the Snohomish Basin is not known, but the surface area covered by these bodies can be used to provide at least a comparative indication of the amount of water that is stored. The total lake surface in the basin is about 21.5 square miles, of which about 4.4

PHOTO 6-4. Seattle Water Department diverts water from the South Fork of the Tolt River for use in the Cedar-Green basin.

square miles consists of regulated reservoirs. The total surface area of glaciers in the basin is about 1.8 square miles. The most extensive glacier system is in the upper watershed of the South Fork Skykomish River.

The Snohomish County Public Utility District and the city of Everett have jointly undertaken a dam and reservoir project on the Sultan River which presently provides 34,500 acre-feet of water supply storage for Everett. Provisions have been made for additional storage and hydroelectric facilities in the future. Lake Chaplain provides intermediate storage for 14,000 acre-feet of municipal water from the Sultan River. The construction of additional storage facilities may have an important effect on the flow regimen of the Sultan River. Flows presently drop to less than 100 cfs during the summer, yet the diversion capability of the Everett system is already 180 cfs. and future diversion capability is planned to be approximately 490 cfs.

Quality

Water quality of the Snohomish River Basin has been measured since July 1959 as part of a cooperative State-Federal basic data program conducted by the Washington State Department of Water Resources, Washington State Water Pollution Control Commission, and the U.S. Geological Survey. the Water Quality for five stations in the basin is shown in Table 6-6.

Physical. Temperature records available for Snohomish basin streams show the following data: the January minimum temperatures recorded at the existing stations range from 0°C (32°F) to 1.2°C (34°F); the maximum temperature of the Snoqualmie River near Carnation has reached 23.30°C (74°F), the highest recorded in the basin. The maximum temperatures for the Skykomish and Wallace Rivers near Gold Bar are 19.4°C (67°F) and 21.1°C (70°F), respectively. The maximum temperature for the Tolt River is 20.0°C (68°F). The average summer temperature remains highest for the Snoqualmie River near Carnation.

The Snohomish River is less turbid than most other streams on the east side of Puget Sound. The turbidity of the Snohomish River at Snohomish was 16 JTU during 7 years of daily or monthly sampling. Maximum turbidity at this station (during a period of storm runoff) was only 160 JTU. (See Table 6-6.) The Skykomish River is appreciably less turbid than the Snohomish River, and the Snoqualmie River

slightly more turbid than the Snohomish River. The upper drainage areas transport only small amounts of sediment except during periods of high runoff. Data concerning suspended sediment in the Snoqualmie River system indicate that the South Fork of the Snoqualmie transports more sediment than other forks of the river. Suspended sediment concentrations ranged from 4 to 108 mg/1 with a probable maximum estimated to be less than 1,000 mg/1. Concentrations in the Skykomish River ranged from 1 to 28 ppm during 1965 and 1966. The Tolt River transports only small quantities of sediment except during periods of high runoff.

Chemical. The chemical quality of surface waters in the Snohomish Basin is generally excellent. The concentration of dissolved solids in waters of the Snohomish, Skykomish, and Snoqualmie Rivers rarely exceeds 40 mg/1. Hardness values are usually less than 25 mg/1. Table 6-6 lists data reduced from records gathered at 7 monitoring stations since 1947.

Dissolved oxygen (DO) concentrations are usually near saturation throughout the Snohomish River system. The minimum DO concentration recorded within the basin is 8.3 mg/l taken from the Snohomish River at Snohomish. The maximum recorded concentration is 14.7 mg/l taken from the Tolt River at Carnation.

Bacteriological. Water of the Skykomish River at Gold Bar is generally of excellent bacteriological quality, with coliform densities usually not more than 50 MPN. However, coliform concentrations increase in the lower Skykomish River before it joins the Snoqualmie River. Bacteriological quality data for the Snoqualmie River at Snoqualmie show the MPN values to be highly variable. During the summer and fall months, MPN values have reached 4,600 or more coliforms per 100 ml. Data from the Snohomish River at Snohomish reflect the composite effect of the upper two rivers in addition to the effects of waste discharged below their confluence. Coliform densities average about 2,000 MPN with a recorded maximum of 24,000 coliforms per 100 ml.

GROUND WATER

Quantity Available

Plentiful supplies of ground water exist in many of the lowland areas of the basin, particularly along the lower reaches of the longer streams. However, in some districts little or no ground water has been found below the soil zones. Areas commonly deficient in ground water are: (1) the northeast part of the Cedarhome plateau northeast of U.S. Highway 99, (2) the Cathcart district, (3) the northeast part of the Getchell Hill plateau, (4) the East Stanwood hill area, (5) the north side of the Lake Stevens area, and (6) the Alderwood Manor-Sammamish River area.

Large yields are obtained from wells tapping clean gravel. Among these are the city well at Arlington and the dug wells at Monroe, whose capacities of 1,000 gpm are among the largest in the county. Shallow wells in the vicinity of Marysville also show large yields; quantities of 190 to 200 gpm are commonly pumped for sprinkler irrigation from wells only 10 or 15 feet deep, and with no more than two or three feet of drawdown. Ground water in these areas is usually in balance with nearby water bodies. The ground waters are recharged by infiltration of surface runoff and, during periods of high water in the rivers, by infiltration from the main streams and their tributaries.

Quality

Most ground waters are generally low in dissolved solids with concentrations being usually less than 200 mg/l. Hardness of water taken from alluvial materials is approximately 50 mg/l, and that from deeper sands and gravels varies from about 15 mg/l to 150 mg/l. Silica concentration is commonly in the 20-40 mg/l range.

The presence of salt water often occurs in ground water in the flood plain and delta areas downstream from Snohomish and at some places along the shoreline. Salinity of ground water is generally less than 15 mg/l of chloride except for wells in the lower flood plain and delta regions where brackish waters are common.

Iron is the most common objectionable constituent in the ground waters of Snohomish County. Iron concentrations as high as 9 mg/l have been found in many well waters. This high iron content is especially prevalent where peat or boggy soils are present. Ground waters in the Marysville Trough and the Snohomish and Skykomish Valleys below Monroe, some of the richest lands in the area, contain amounts of iron in excess of 0.3 mg/l. Table 6-7 lists ground water quality data for selected wells in King and Snohomish Counties.

TABLE 6-6. Surface water quality.

Item	Discharge (cfs)	Dissolved solids (mg/l)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4) (mg/l)	Total phosphate (PO_4) (mg/l)	Silica (SiO_2) (mg/l)	Iron (Fe) (mg/l)	Boron (B) (mg/l)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen (mg/l)	Oxygen saturation (%)	Total (mg/l)	Noncarbonate (mg/l)	Coliform (MPN)
		mg/l												mg/l									mg/l		mg/l		
SKYKOMISH RIVER NEAR GOLD BAR — JULY 1959 THROUGH 1966																											
Maximum	23,700	38	5.2	1.1	2.3	0.9	181	0	4.0	2.6	0.2	0.6	46	0.06	—	7.6	0.52	0.06	7.5	20	20	18.3	13.9	122	18	7	2,400
Mean	—	23	3.8	0.5	1.5	0.5	19	0	2.0	1.1	0.0	0.3	32	0.01	—	5.5	0.09	0.02	—	—	—	8.8	11.6	102	12	0	174
Minimum	749	13	2.0	0.1	0.6	0.2	10	0	0.6	0.2	0.0	0.0	20	0.00	—	3.6	0.01	0.00	6.5	0	0	2.6	9.6	92	7	0	0
Number	31	38	38	38	36	38	38	23	38	38	37	38	38	33	—	38	34	12	37	36	15	37	37	37	38	38	37
SULTAN RIVER NEAR STARTUP — JULY 1960 THROUGH 1966																											
Maximum	—	23	4.1	0.7	1.4	0.6	15	—	3.2	0.9	—	0.1	—	—	—	5.8	0.07	—	—	—	—	—	—	—	13	—	—
Mean	—	23	4.1	0.7	1.4	0.6	15	—	3.2	0.9	—	0.1	—	—	—	5.8	0.07	—	—	—	—	—	—	—	13	—	—
Minimum	—	23	4.1	0.7	1.4	0.6	15	—	3.2	0.9	—	0.1	—	—	—	5.8	0.07	—	—	—	—	—	—	—	13	—	—
Number	—	1	1	1	1	1	1	—	1	1	—	1	—	—	—	1	1	—	—	—	—	—	—	—	1	—	—
SULTAN RIVER AT SULTAN — JULY 1960 THROUGH 1966																											
Maximum	—	56	9.0	2.4	3.3	0.9	38	0	4.8	1.8	0.2	0.8	73	0.07	—	10.0	2.30	0.06	8.1	20	75	21.3	13.7	122	31	2	930
Mean	—	27	4.8	0.8	1.3	0.3	18	0	2.8	0.8	0.1	0.4	38	0.01	—	5.2	0.41	0.01	—	—	—	9.9	11.2	102	15	0	88
Minimum	—	15	2.0	0.1	0.6	0.0	9	0	0.6	0.2	0.0	0.1	20	0.00	—	2.6	0.01	0.00	3.9	0	0	3.5	8.5	80	8	0	0
Number	—	35	35	35	35	35	35	20	35	35	35	35	36	31	—	35	31	12	35	11	16	34	35	34	35	35	35
SNOQUALMIE RIVER AT SNOQUALMIE — JULY 1959 THROUGH 1966																											
Maximum	2,610	33	6.0	1.0	1.8	0.8	22	0	3.0	1.5	0.3	1.8	46	0.12	—	7.9	4.80	0.06	7.4	40	40	17.5	13.2	111	18	2	4,600
Mean	—	26	4.1	0.4	1.2	0.4	15	0	2.0	0.7	0.0	0.5	32	0.02	—	5.7	0.59	0.01	—	—	—	9.1	11.1	99	12	0	1,439
Minimum	134	14	1.5	0.0	0.7	0.1	7	0	0.0	0.2	0.0	0.0	16	0.00	—	3.1	0.02	0.00	6.2	5	5	3.2	9.0	86	6	0	0
Number	15	34	34	34	34	34	34	22	34	34	34	34	34	31	—	34	31	10	34	34	14	36	36	36	34	34	35
TOLT RIVER NEAR CARNATION — JULY 1960 THROUGH 1966																											
Maximum	2,340	47	8.0	1.9	2.1	0.7	32	0	5.8	1.2	0.1	1.0	66	0.03	—	10.0	1.80	0.05	7.5	30	50	23.2	14.7	122	27	2	430
Mean	—	33	5.2	1.0	1.6	0.3	20	0	3.7	0.8	0.0	0.4	43	0.01	—	7.2	0.33	0.01	—	—	—	10.6	11.1	102	17	1	84
Minimum	90	21	3.0	0.3	1.0	0.0	10	0	2.2	0.2	0.0	0.1	24	0.00	—	3.8	0.03	0.00	6.6	0	0	3.7	8.7	86	9	0	0
Number	27	34	34	34	34	34	34	19	34	34	34	34	34	31	—	34	31	11	34	34	15	34	35	34	34	34	34
SNOQUALMIE RIVER NEAR CARNATION — 1947 THROUGH 1948																											
Maximum	7,600	42	7.2	1.0	—	—	29	—	5.4	1.0	0.2	0.9	59	—	—	10.0	0.06	0.01	7.2	—	—	—	—	—	22	2	—
Mean	—	39	6.6	1.0	—	—	25	—	4.6	0.9	0.2	0.7	51	—	—	9.6	0.05	0.01	—	—	—	—	—	—	21	1	—
Minimum	880	36	6.0	1.0	—	—	21	—	3.8	0.8	0.2	0.5	42	—	—	9.2	0.05	0.01	7.2	—	—	—	—	—	19	0	—
Number	2	2	2	2	—	—	2	—	2	2	1	2	2	—	—	2	1	1	1	—	—	—	—	—	2	2	—
SNOHOMISH RIVER AT SNOHOMISH — AUGUST 1959 THROUGH 1966																											
Maximum	40,800	40	7.2	1.6	3.1	0.9	27	0	4.0	2.2	0.2	2.6	62	0.12	—	11.0	3.20	0.06	7.4	20	160	19.0	14.0	128	22	2	24,000
Mean	—	30	4.5	0.9	1.8	0.5	18	0	2.7	1.2	0.1	0.7	40	0.02	—	6.4	0.38	0.02	—	—	—	10.0	11.0	100	15	0	2,050
Minimum	10,000	14	2.0	0.2	0.8	0.0	10	0	0.8	0.0	0.0	0.0	20	0.00	—	3.3	0.04	0.00	6.4	0	0	4.0	8.3	89	8	0	23
Number	19	59	59	59	59	59	59	36	59	59	59	59	59	48	—	59	45	8	59	58	43	62	62	62	59	59	62

TABLE 6-7. Ground water quality.

Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids	Hardness ($CaCO_3$)	Specific conductance (μmho)	pH
				(mg/l)											
City of Edmonds	27/3-24Q3	12/18/59		36	0.00	9.5	9.4	5.9	2.1	3.3	0.21	113	62	160	7.6
Alderwood Manor Water Dist.	27/4-10N1	12/1/59	40	45	0.00	13	6.1	7.8	2.7	0.2	0.60	123	58	156	7.7
Albert Weishaupt	27/6-13M	6/22/60	58	16	0.07	10	3.6	4.1	0.9	9.8	0.01	72	40	105	6.4
D. R. Smith	27/7-5L	6/23/60	65	13	31[t]	14	6.2	5.0	1.7	0.1	0.01	80	60	146	6.6
Snohomish County PUD No. 1	28/5-7G2	10/13/60	51	33	0.05	10	10	5.3	1.7	6.9	0.17	113	67	162	7.5
C. R. Cedergreen	28/6-29H1	10/12/60	53	27	0.95[t]	20	9.2	14	1.6	9.4	0.11	159	88	239	6.8
Floyd McKennon	28/6-34A	6/22/60	62	28	1.5[d]	16	7.9	8.6	3.1	0.6	0.43	120	72	190	7.6
Stokley Van Camp Co.	28/6-35E2	10/12/60	52	23	0.07	10	3.8	36	2.0	0.3	0.98	156	41	257	7.8
Lester Thayer	28/7-28N1	10/6/60	51	21	0.03	11	7.1	4.3	0.6	10	0.05	96	57	137	7.0
City of Marysville	29/5-2C1	12/18/59	48	25	0.81	18	7.5	6.1	1.3	0.2	0.69	118	76	179	7.8
Soundview Pulp Co.	29/5-19K1	11/18/44	31	31	0.37	16	16	14	4.7	0.06		171	106	280	

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

PRESENT AND FUTURE NEEDS

The primary factors that dictate water requirements are industrial and population growth. Projections to the year 2020 for the Snohomish basin indicate a substantial growth in both population and industry with a corresponding increase in water requirements. Available data indicate that while the predicted requirements for water will not tax the available water supply, extensive planning is in order to ensure adequate storage facilities to meet predicted water requirements in this and adjacent basins.

PROJECTED POPULATION GROWTH

The 1965 Snohomish Basin population of 201,300 is projected to increase approximately 59 percent to 302,700 by 1980, 155 percent to 485,800 by year 2000, and 310 percent to 780,300 by the year 2020. Figure 6-3 shows present and projected population in the basin. Possibly the growth shown for "other urban and rural communities" will not be as is indicated in Figure 6-3, because of the Everett service area may absorb part of this projected growth. The Major part of the projected growth will tend to center around the Everett area, following the industrial growth pattern.

PROJECTED INDUSTRIAL GROWTH

The major water consuming industries are expected to show a value added growth of 300 percent between the present and the year 2020 (see Figure 6-4). The greatest growth is expected to take place in pulp and paper manufacturing; lumber production is projected to show a gradual, steady decline through 2020 as emphasis shifts from lumber production to pulp and paper production. This will tend to concentrate growth in the vicinity of Everett, with growth in the outlying areas being much slower. Food and kindred processing in the basin is forescast to increase moderately through the year 2000, then increase sharply through 2020 as population growth accelerates in the basin and adjacent areas.

PROJECTED WATER REQUIREMENTS

Total water requirements for the basin are expected to reach 540 mgd, a threefold increase in water needs over present requirements. Figure 6-5 shows the location by service area of water use requirements in 20-year increments. Tables 6-8, 6-9, and 6-10 detail projected water use in the basin for 1980, 2000, and 2020, respectively. Table 6-11 summarizes projected requirements for the various use categories through the year 2020. Figure 6-6 illustrates the relative demands for water in the basin through 2020.

Municipal

Municipal water requirements are forecast to be 49 mgd by 1980, 92 mgd in 2000, and 171 mgd by the year 2020. By 2020, municipal requirements will account for approximately 31 percent of the total basin water needs, with per capita use increasing from a present 150 gpd to approximately 208 gpd in 2000, and 230 gpd by the year 2020. This per capita water use is in line with the general trend in personal water use observed in other expanding urban areas.

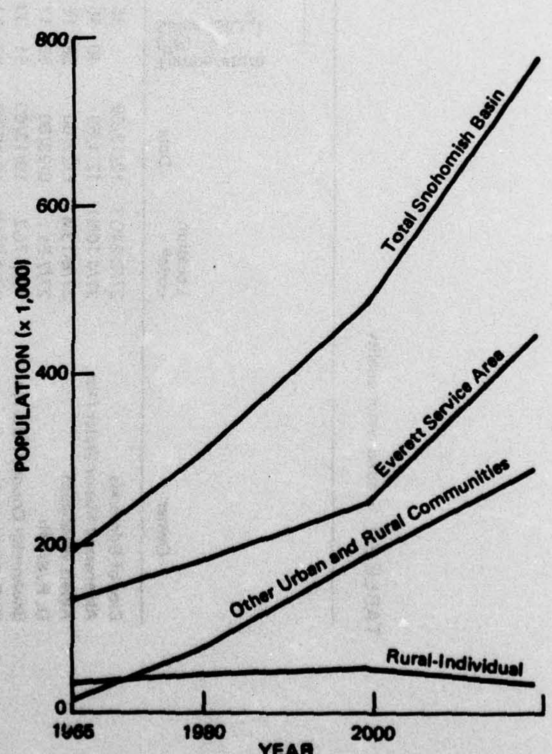


FIGURE 6-3. Projected population growth.

TABLE 6-8. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd)		Ground water usage (mgd)	
		Average daily	Maximum monthly	Average daily	Maximum monthly
Everett Service Area	79,200	34.2	47.9	—	—
Alderwood Water District	(93,600)	(17.8)	(24.9)	—	—
Monroe	(7,200)	(1.4)	(1.9)	—	—
Marysville	11,966			0.6	0.8
Snohomish	10,731	3.0	4.1		
Edmonds[a/]	27,020	7.4	10.3		
Snoqualmie	7,257			0.4	0.5
North Bend	5,327	1.5	2.1		
Carnation	3,320			0.1	0.2
Fall City Water Company	3,242			0.1	0.2
Skykomish Water District	1,312			0.1	0.1
Duvall[b/]	1,390	0.4	0.5		
Other River & Community Systems	5,636	1.0	1.6	0.1	0.2
Subtotal	257,200	47.5	66.5	1.4	2.0
RURAL-INDIVIDUAL USE	45,500	—	—	3.2[a]	4.5
INDUSTRIAL USE					
Everett					
Paper and allied	—	167.0	184.0[b]	—	—
Lumber and wood	—	1.6	1.8[b]	—	—
Chemicals, metals, oils	—	0.2	0.2	—	—
Stone, clay, glass	—	0.6	0.6	—	—
Snohomish					
Food and kindred	—	2.6	4.0[c]	—	—
Self-supplied:					
Paper and allied	—	41.0	45.0[b]	—	—
Stone, clay, glass	—	0.3	0.3	0.8	1.2[c]
Subtotal	—	213.2	235.8	0.8	1.2
Total	302,700	260.7	302.3	5.4	7.7

[a] Based on assumed 70 gpcd and 100 percent served by ground water by 1980.

[b] 110 percent of average.

[c] 150 percent of average.

TABLE 6-9. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
Everett Service Area	250,000	52.5	73.5		
Alderwood Water District	(130,000)	(27.3)	(38.2)		
Monroe	(10,000)	(2.1)	(2.9)		
Marysville	29,016			0.8	1.1
Snohomish	26,021	8.3	11.7		
Edmonds[a]	65,520	20.7	29.0		
Snoqualmie	17,597			0.5	0.7
North Bend	12,917	4.1	5.8		
Carnation	8,050			0.2	0.3
Fall City Water Company	7,862			0.2	0.3
Skykomish Water District	3,182			0.1	0.1
Duvall[b]	3,370	1.1	1.5		
Other Rural & Community Systems	13,661	3.1	4.3	0.1	0.2
Subtotal	437,200	89.8	125.8	1.9	2.7
RURAL-INDIVIDUAL USE	48,600	—	—	4.4[a]	6.2
INDUSTRIAL USE					
Everett					
Paper and allied	—	265.0	292.0[b]	—	—
Lumber and wood	—	1.5	1.6[b]	—	—
Chemicals, metals, oils	—	0.4	0.4	—	—
Stone, clay, glass	—	1.5	1.5	—	—
Snohomish					
Food and kindred	—	5.2	7.9[c]	—	—
Self-supplied:					
Paper and allied	—	47.0	52.0	—	—
Stone, clay, glass	—	0.7	0.7	2.1	3.0[c]
Subtotal	—	321.1	356.0	2.1	3.0
Total	485,800	410.9	481.8	8.4	11.9

[a]Based on assumed 90 gpcd and 100 percent served by ground water.

[b]110 percent of average.

[c]150 percent of average.

TABLE 6-10. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Everett Service Area	450,000	104.0	145.0		
Alderwood Water District	(234,000)	(54.1)	(75.4)		
Monroe	(18,000)	(4.2)	(5.8)		
Marysville	45,152			1.5	2.1
Snohomish	40,491	14.0	19.8		
Edmonds[a/]	101,955	34.9	49.3		
Snoqualmie	27,382			0.9	1.2
North Bend	20,100	7.0	9.9		
Carnation	12,526			0.4	0.6
Fall City Water Company	12,235			0.4	0.5
Skykomish Water District	4,952			0.1	0.2
Duvall[b/]	5,243	1.9	2.6		
Other Rural & Community Systems	21,264	5.2	7.4	0.2	0.3
Subtotal	741,300	167.0	234.0	3.5	4.9
RURAL-INDIVIDUAL USE	39,000	—	—	4.3[a]	6.0[a]
INDUSTRIAL USE					
Everett					
Paper and allied	—	300.0	330.0[b]	—	—
Lumber and wood	—	1.4	2.0[b]	—	—
Chemicals, metals, oils	—	1.0	1.0	—	—
Stone, clay, glass	—	3.4	3.4	—	—
Snohomish					
Food and kindred	—	9.6	14.5[c]	—	—
Self-supplied:					
Paper and allied	—	47.0	52.0	—	—
Stone, clay, glass	—	0.7	0.7	2.1	3.0[c]
Subtotal	—	363.0	404.0	2.1	3.0
Total	780,300	530.0	638.0	9.9	13.9

[a]Based on assumed 110 gpcd and 100 percent served by ground water.

[b]110 percent of average.

[c]150 percent of average.

TABLE 6-11. Summary of projected water needs

System		Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly	Total usage (mgd) Average daily	MMaximum monthly
Municipal	1965	154,760	22.7	27.6	1.3	2.3	24.0	29.9
	1980	257,200	47.5	66.5	1.4	2.0	48.9	68.5
	2000	437,200	89.8	125.8	1.9	2.7	91.7	128.5
	2020	741,300	167.0	234.0	3.5	4.9	170.5	238.9
Industrial	1965	—	138.3	144.0	0.4	0.7	138.7	144.7
	1980	—	213.2	235.8	0.8	1.2	214.0	237.0
	2000	—	321.1	356.0	2.1	3.0	323.2	359.0
	2020	—	363.0	404.0	2.1	3.0	365.1	407.0
Rural-Individual	1965	35,940	0.2	0.3	1.8	2.5	2.0	2.8
	1980	45,500	–	–	3.2	4.5	3.2	4.5
	2000	48,600	–	–	4.4	6.2	4.4	6.2
	2020	39,000	–	–	4.3	6.0	4.3	6.0
Totals	1965	190,700	161.2	171.9	3.5	5.5	164.7	177.4
	1980	302,700	260.7	302.3	5.4	7.7	266.1	310.0
	2000	485,800	410.9	486.8	8.4	11.9	419.3	493.7
	2020	780,300	530.0	638.0	9.9	13.9	539.9	651.9

Note: All usage figures are rounded to one decimal place.

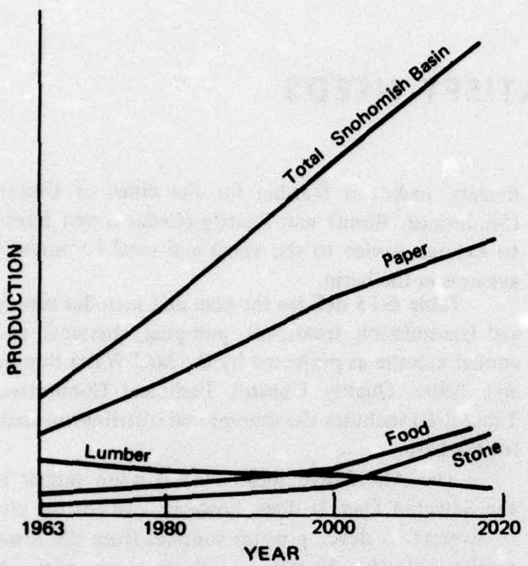


FIGURE 6-4. Relative production growth for major water-using industries.

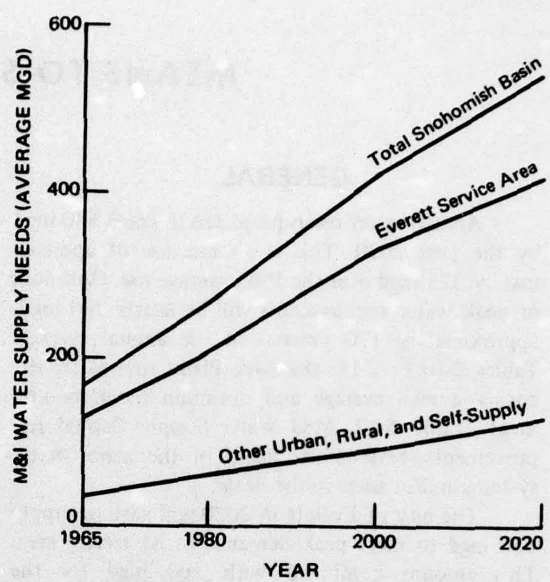


FIGURE 6-5. Location of projected water supply needs.

Industrial

Industries are expected to continue to be the major water consumers in the Basin, and will require approximately 373 mgd, 66 percent of projected Basin water requirements. The pulp and paper industries, food and kindred producers, and the stone, clay, and glass industries are expected to be the major water users. Industrial water needs, presently 138 mgd, are predicted to increase 54 percent by 1980, and to be almost triple by the year 2020.

Rural-Individual

By the year 2020, rural-individual water needs are forecast to be only 4 mgd, less than one percent of the basin's total projected water needs. While this usage represents a marked drop in percentage of the total basin needs, it does indicate a volume increase of approximately 30 percent.

MEANS TO SATISFY NEEDS

GENERAL

Annual water use is projected to reach 540 mgd by the year 2020. This is an increase of approximately 375 mgd over the 1965 average use. Optimum or peak water requirements will be nearly 900 mgd, approximately 170 percent of the annual average. Tables 2-10 or 2-11, the Area Plans, summarize the basins' annual average and optimum water requirement. Table 6-12, M&I Water Supply Capital Improvements, reviews the needs of the major water systems and/or users in the Basin.

The city of Everett in 2020 will have to supply 630 mgd to meet peak demands in its service area. This amount combined with 260 mgd for the remainder of the Basin, plus the fact that the city of Seattle Water Department plans further development of its watershed on the Tolt River and new development on the Snoqualmie River and/or the North Fork of the Skykomish River (see Cedar-Green Basin Selected Plan, Table 7-12), will create monumental demands for water from this basin. This will amount to nearly 2,300 mgd, 890 of this to be used in the Snohomish Basin. With this in mind and the fact that much of the south part of the Snohomish Basin lies within the logical Seattle Service Area, Seattle and Everett must jointly develop bordering service areas to supply the Basin needs.

As indicated in Appendix III, "Hydrology and Natural Environment," adequate water is available for this task without conflict over water supply withdrawals. Together the Everett and Seattle Water Departments may supply over 90 percent of the total basin water needs.

BASIN PLANS

The Selected Plan, as indicated in Table 6-13, recommends the continued growth and development of all existing systems until such time as population density makes it feasible for the cities of Everett (Snohomish Basin) and Seattle (Cedar-Green Basin) to extend service to the small and rural community systems in the basin.

Table 6-13 defines the plan and includes supply and transmission, treatment, pumping, chemical, and annual income as projected by the M&I Water Supply and Water Quality Control Technical Committee. Table 2-10 includes the storage and distribution costs for the basin.

The Alternative Basin Plan is quite similar to the Selected Plan. It does, however, call for the city of Everett to develop water supplies from the lower reaches of the Snohomish River with adequate treatment to assure high quality water. Costs for this alternative are appreciably higher, $9 million, than for the Selected Basin Plan. This is due mainly to construction costs for the water treatment facilities. Table 6-14 defines the plan and Table 2-11 shows complete costs and revenue for the Basin.

The city of Everett in the Selected Plan is expected to continue development of the Sultan River Reservoir and Spada Lake as a water supply source to the year 2000. During this time period, a development on the Skykomish River is also expected to be added. The developments in the Selected Plan would be adequate to meet the M&I needs of the city of Everett.

The 200 plus mgd needed for the small and rural community systems are anticipated to be supplied by the cities of Everett and Seattle at such time as a county or regional service is possible. Because much of the Basin lies within the logical Seattle Service Area, with projected developments (Table 7-12) on the Tolt, Snoqualmie, and Skykomish Rivers, Seattle and Everett will jointly supply water within the Basin.

Much of the self-supplied industrial demand is not required to be of a high quality; therefore, it has in the past and will more than likely in the future be supplied by local developments of surface or ground water.

Table 6-12 shows the need for water within the basin.

FINANCE

Annual income as taken from Table 2-10 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 years at 5% for the Selected and Alternative Plans.

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. At this rate, by the year 2000, the basin will be unable, without an excessive financial burden in relation to its economic resources, to finance adequately the needed construction projects without outside aie or increasing water rates.

Year	Bond Service Available (x 1,000)	Annual Amortized Cost (x 1,000) Selected Plan	Alternative Plan
1965	$2,720	$ 376	$ 373
1980	4,110	1,870	1,880
2000	6,550	2,850	3,020
2020	6,860	4,390	4,750

TABLE 6-12. M & I Water Supply—Capital Improvements in the Snohomish Basin

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	135,000	180,000	259,000	450,000
EVERETT				
Optimum	197.5	305.0	460.0	632.5
Capital Improvements	27.5	107.5	155.0	172.5
Population Served	19,760	77,200	187,200	291,300
SMALL & RURAL COMMUNITY SYSTEMS				
Optimum	14.9	54.8	131.1	206.2
Capital Improvments	9.1	39.9	76.3	75.1
Population Served	---	---	---	---
SELF SUPPLIED INDUSTRY				
Optimum	34.1	46.5	55.7	55.7
Capital Improvements	1.6	12.4	9.2	0
Population Served	154,760	257,200	428,200	741,300
TOTAL				
Capital Improvements	38	160	241	248

NOTE: Figure are rounded.

TABLE 6-13. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Snohomish Basin

					OPTIMUM CAPACITY M G D		1967 THOUSAND DOLLARS					
							AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
EVERETT												
Present	SW	Sultan River—Dam and Reservoir—Spada Lake, 4 Transmission Lines	Exist.	125	170	170				1,324	60	9,192
Present	SW	ADD: 280mgd SW Development to Existing	1970	28	28	28	3,575					
1980	SW	108mgd SW Development to Existing Sultan River Development	1970	204	108	107	13,975			2,138	81	14,892
2000	SW	[a]155mgd SW Development to Existing Sultan River & Skykomish River Diversion: T28N S10E	1995	321	155	155	10,500		3,369	128	23,433	
2020	SW	172mgd SW Development to Skykomish River	2005	410	172	172	13,700			4,303	164	23,944
					633	633	$41,750					
EVERETT SELECTED PLAN TOTAL							$41,750					
			SMALL & RURAL COMMUNITIES SUB-TOTAL				$8,115					
			EVERETT TOTAL				$49,865					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local GW Development	Exist.	4	1.2	1.2						467
Present	SW	Local SW Development	Exist.		1.6	1.6				38	1	
					2.8	2.8						
Present	SW	[a]ADD: 9.0mgd from Everett Water Department	1970		9	9	546					
1980	GW	3.0mgd Local GW Development	1970		3	3	180				7	1,241
1980	SW	20mgd—Everett Water Department	1970	17	20	20	1,200					
	SW	20mgd—Everett Water Department	1970		20	20	1,000	1,493		181		
2000	SW	[a]60mgd—Seattle Water Department	1985	44	60	60	4,280			633	24	3,504
	SW	16mgd—Everett Water Department	1990		16	16	1,279	2,873				
2020	SW	45mgd—Everett Water Department	2010	76	38	38	2,280			788		
	SW	30mgd—Everett Water Department	2015		38	37	1,810	2,775			30	4,438
					208	208	$12,575	$7,140				
SMALL & RURAL COMMUNITY SYSTEMS SELECTED PLAN TOTAL							$19,715					
			($12,575 Break-down)									
			Local Ground Water Development				180					
			Seattle Water Department				4,280					
			Everett Water Department				8,115					
SELF SUPPLIED INDUSTRY												
Present	SW	Snohomish River Pump Station	Exist.	33	35	35				350		2,409
1980	SW	15mgd SW Development	1978	42	15	15	900			460		3,086
2000	SW	10mgd SW Development	1990	50	10	10	650			530		3,860
2020	SW	No Future Needs		50								3,860
SELF SUPPLIED INDUSTRY SELECTED PLAN TOTAL					60	60	$1,550					
SELECTED BASIN PLAN TOTAL							$71,130					

[a] Initital development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 6-14. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Snohomish Basin

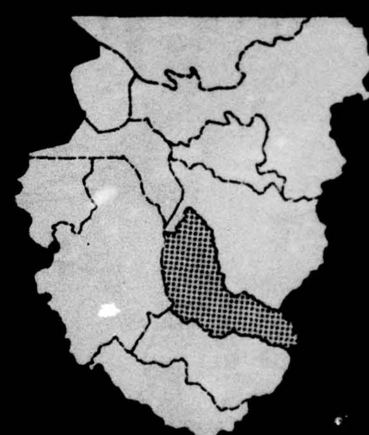
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D Supply	OPTIMUM CAPACITY M G D Transm.	1967 THOUSAND DOLLARS — AMORTIZED CAPITAL COST[b] Supply & Transm.	AMORTIZED CAPITAL COST[b] Treat-ment	AMORTIZED CAPITAL COST[b] Iron Removal	MAINTENANCE AND OPER. Pumping Power	MAINTENANCE AND OPER. Chem.	Total Annual Income
EVERETT												
Present	SW	Sultan River—Dam & Reservoir—Spada Lake, 4 Transmission Lines	Exist.	25	170	170					50	9,198
Present	SW	ADD: 28mgd and Improvement 4 Transmission Lines	1970		28	28	3,575			1,000		
1980	SW	SW Development, Sultan River	1980	204	108	108	13,975			2,137	81	14,892
2000	SW	156mgd SW Development Sultan River & Snohomish River Treatment	1995	321	156	156	8,150	7,500		3,369	128	23,433
2020	SW	SW Development, Snohomish River	2005	410	172	172	11,425	12,900		4,302	164	23,944
					633	633	$37,125	$20,400				
EVERETT ALTERNATIVE PLAN TOTAL						(64.)	$57,525					
SMALL & RURAL COMMUNITY SYSTEMS (No Feasible Alternative)												
SELF SUPPLIED INDUSTRY (No Feasible Alternative)												
					901	901	55,875	7,140				
ALTERNATIVE BASIN PLAN TOTAL						(67)	$78,790					

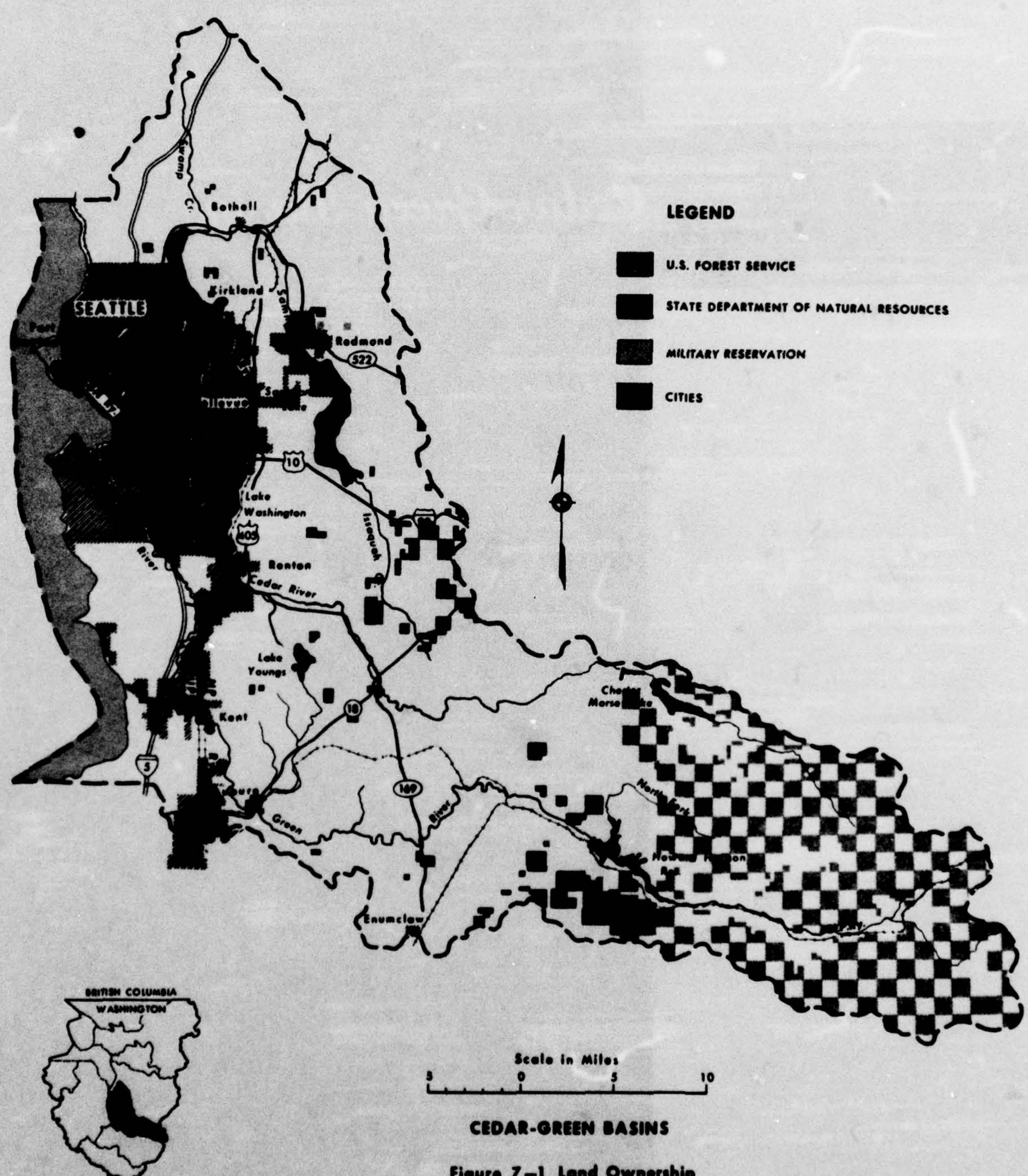
[a] Initial development.

[b] Does not include storage and distribution costs: See *Area Means to Satisfy Needs* section.

[c] All figures are rounded.

Cedar-Green Basins





CEDAR-GREEN BASINS

Figure 7—1 Land Ownership

CEDAR-GREEN BASINS

INTRODUCTION

Most of the Cedar-Green basin (figure 7-1) is located in highly populated and industrialized King County. The basin is bordered by the Snohomish basin on the north, Puyallup basin on the south, the Cascade Mountain range on the east, and Puget Sound on the west. It comprises 1,220 square miles, including 1,161 square miles of land and inland water, and two important watersheds: Lake Washington, receiving water from the Cedar and Sammamish Rivers, and the Green River.

Population and industry in the western part of the Basin are growing and expanding. Urbanization is increasing, with Seattle as the focal point. By the year 2020, the population in the Seattle service area is expected to increase to more than 3,816,300 million. Industry, particularly manufacturing and shipping, is expected to increase substantially.

GEOGRAPHY

The basin was formed during the retreat of the most recent ice sheet some 12,000 to 14,000 years ago. This left a deep mantle of gravel, sand, and clay and formed the plains and sloping moraines that now characterize the basin. As the ice retreated, numerous lakes and ponds were left in the uneven surface. Lakes Washington and Sammamish, as well as many smaller lakes and bays, were formed in this manner. Older forms of relief were smoothed over. Streams were dammed and diverted into new courses, which produced the present rolling or hummocky relief with local lakes, basins, and depressions. The Cedar-Green basin includes 69 square miles of fresh water surface and three major rivers: the Green-Duwamish, Cedar, and Sammamish.

The Green-Duwamish River drains an area of 483 square miles, and is the largest river in the basin. The Green River originates in the Cascade Mountains and flows west and north about 60 miles to Tukwila, from where it is called the Duwamish River. The Duwamish flows north an additional 12 miles through Seattle and empties into Elliott Bay. In its upper reaches, the Green River is swift and turbulent. Since 1913, the upper reach has been the source for Tacoma's municipal and industrial water supply. Howard A. Hanson Dam (photo 7-1) is located at Eagle Gorge. The reservoir behind the dam has a capacity of 105,650 acre-feet for flood control and provides 62,000 acre-feet of active storage for Tacoma water supply and conservation. Below Howard A. Hanson Dam, the Green River has cut a deep gorge 12 miles long with walls as high as 300 feet. Beyond the gorge, the Green flattens out and meanders through the farmlands near Auburn and Kent. The lower Duwamish flows through a heavily industrialized section of Seattle. The last 7 miles, known as the Duwamish Waterway, have been dredged and improved for navigation. The Duwamish Waterway is one of the most industrialized areas in the state.

The Cedar River begins near the crest of the Cascade Mountains, 5,000 feet above sea level. It flows northwesterly through timbered country for 50 miles to discharge into Lake Washington, and drain an area of 188 square miles. In the reaches above the Seattle Landsburg intake, the river is isolated and protected. This area—the Cedar River watershed, drains about 143 square miles. Within the watershed is Chester Morse Lake (Photo 7-2) which provides 56,000 acre-feet of storage for water supply and hydroelectric power generation. At the western end of the watershed near Landsburg, a low-crest dam diverts water from the Cedar into the Seattle transmission mains. Below Landsburg, the river flows swiftly through Maple Valley, thence to Renton, where it empties into the south end of Lake Washington.

The Sammamish River is a slow-moving stream about 14 miles long, which drains a 240 square-mile area. Its source is Lake Sammamish and its outlet at the north end of Lake Washington. Lake Sammamish, with a surface area of 4,897 acres and a maximum depth of 106 feet, is fed primarily by Issaquah and Tibbetts Creeks.

PHOTO 7-1. Howard Hanson Dam provides flood control and stores water for use in Tacoma, an example of inter-basin diversion.

PHOTO 7-2. Chester Morse Lake has been developed for both municipal water supply and power generation.

Lake Washington, a fresh-water lake 22 miles long, forms the eastern boundary of Seattle. It covers about 50 square miles. The Lake Washington Ship Canal leads westward from the lake into Puget sound. The canal and Hiram Chittenden Locks connect Puget Sound with the inland fresh waters of Salmon Bay, Lake Union, Portage Bay, Union Bay and Lake Washington. All these water bodies have the same level and are connected by unobstructed channels at least 30 feet deep at low lake level. The complex has a total area of 25,000 acres and a shoreline of about 100 miles.

Green Lake in north Seattle has a water surface area of 256 acres and a shoreline of 2.9 miles. It is used extensively for outdoor recreation and is ringed with a park, hiking and bicycle path, and beaches, but does not contribute to municipal and industrial water supply.

CLIMATE

Climate is influenced by the mild, moist air flowing inland from the Pacific Ocean. In general, the basin has warm, dry summers and comparatively mild, wet winters. Temperatures in the western lowlands near Seattle and Kent average about 3.3° to 4.4° C (38° to 40° F) in January. Midsummer temperatures in July average 17.2° to 18.3° C (63° to 65° F). The mean annual precipitation averages 66 inches in the Cedar and Green watersheds and 54 inches in the Sammamish River watershed. Annual precipitation for the entire basin ranges from 15 inches near Puget Sound to 100 inches in the mountains. About three-fourths of the precipitation falls from October through March; only 8 percent falls during June, July, and August. However, snowpack evens out the runoff flow.

POPULATION

The Cedar-Green Basin, with an estimated 1965 population of 1,040,220, is the most populated of the study basins. Seattle is the largest city, with some 580,000 dwellers inside the city limits. Half as many persons live in suburbs, and a number of nearby residential communities. Farther east are several small towns with populations of 1,000 to 2,500 persons and a number of communities with populations of less than 1,000. The southeastern part of the basin is sparsely populated.

ECONOMY

The major center of economic activity in the basin, and for the entire Pacific Northwest, is the metropolitan Seattle area in King County. Seattle, largest city in Washington, has excellent deep harbor facilities. Major industries include forest product processing, fishing, shipping, and manufacturing. Elsewhere in the basin, the principal products and indus-

tries are manufacturing, forest products, diversified farming, fishing, and coal mining. In 1965, average monthly employment in the various industries throughout King County was:

Agriculture	4,100
Mining	1,700
Construction	17,700
Manufacturing	106,900
Transportation, communication, and utilities	57,000
Trade (wholesale and retail)	84,300
Finance, insurance, and real estate	24,300
Services	50,000
Government	61,800
Not classified	47,100

A major industry in the basin is the manufacture of jet airplanes and research, development, and production of missiles and advanced spacecraft. The Boeing Company, with headquarters in Seattle, employed more than 98,800 persons with an annual payroll of more than $900 million as of June 1967.

Elliott Bay, which forms Seattle's natural deepwater harbor, is one of the finest seaports in the world, covering more than 5,300 acres. Its waterfront is lined with modern terminals equipped to handle many types of cargo. The Port of Seattle, a municipal corporation, operates marine and airport terminals, develops sites for water-oriented industries, and promotes commerce. Air traffic and the movement of marine cargoes yield a gross annual volume of $600 million and employ more than 28,000 persons, producing an annual payroll in excess of $200 million.

Although the aerospace industry predominates, many other industries, such as shipbuilding, forest products, food processing, and metals, also exist in the basin. Heavy industrial development is concentrated along the lower reaches of the Green-Duwamish River valley and in the Seattle-Renton metropolitan area. Light industry is considerably more dispersed. Dairying, truck gardening, poultry raising, and some light industry are the chief supports of the economy in the fertile valleys of the Green, Cedar, and Sammamish Rivers.

Industry and population have grown rapidly. The rate of employment growth in the Seattle-Tacoma-Everett area for 1966 was double that of other West Coast metropolitan areas and the nation as a whole. By April 1966, employment in the Seattle metropolitan area alone was 47,800 above the same month in the previous year. Employment by The Boeing Company grew by 50 percent. Personal income showed a substantial gain as the population expanded.

LAND USE

Land use in the Cedar-Green Basins varies from intense residential, commercial, and industrial uses in the city of Seattle, to undeveloped cutover lands and second-growth timber in the eastern portions. Forestlands predominate in the basin, accounting for 63 percent of the total land use. Most of this acreage lies in Federally administered Snoqualmie National Forest. Approximately seventy percent (70%) of which is privately owned. Urban buildup is significant, accounting for 22 percent of the land area. This includes the metropolitan area of Seattle, with its nearby cities and suburban residential areas. Agricultural land uses are concentrated in the Green and Sammamish River valleys with marginal uses in the upland areas. Table 7-1 shows land use in the Basin.

TABLE 7-1. General land use.

Use	Acres
Forestland	447,000
Cropland	53,000
Rangeland	3,000
Other land	34,000
Urban buildup	167,000
Inland water	39,000
Total land and inland water	743,000

Source: Appendix III, Hydrology.

PRESENT STATUS

WATER USE

Surface and ground water used for municipal industrial, and rural-individual purposes averages about 165.4 million gallons daily (Table 7-10). No ground water supplies are used in the Seattle area. Nearly all small population centers outside the Seattle city limits, however, including rapidly growing Renton, and Kent, rely mainly on ground water supplies. Table 7-2 summarizes water use in the Basin in 1965.

Municipal

The total amount of surface and ground water used primarily for municipal and domestic purposes averages 108 mgd, or more than 65 percent of the total basin water consumption. The average per capita water consumption in municipalities throughout the Basin is about 103 gallons per day (gpd).

Seattle uses more than 85 percent of the total municipal water supplied in the basin. Figure 7-2 shows Seattle water consumption from 1950 through 1966. Average consumption increased from 80 mgd in 1950 to about 125 mgd in 1966, for an estimated served population of 918,000 residents.

Figure 7-3 shows the Seattle water demand profile based on data fro the period from 1950 to 1966. July through October shows the greatest demand. During July and August municipal water consumption for 30 consecutive maximum days is about 140 percent of the annual average water use; the 7 consecutive maximum days is about 160 percent. This shows the impact of lawn sprinkling and other domestic uses during the summer. Water use reaches a low in March of less than 80 percent of the annual average water use.

Industrial

Industry in the basin uses about 56.8 mgd, or 34 percent of the total water consumption. Most of the industrial water is supplied by the Seattle water system. Industry is heavily concentrated along the shores of Elliott Bay, the Duwamish Waterway (photo 7-3) and the Lake Washington Ship Canal. Industries currently use in excess of 19.47 mgd from the Seattle municipal system.

In Renton, industry uses 1.07 mgd. Industries in the Green River Valley, Auburn, and Kent use about 0.55 mgd. Scattered throughout the basin are industries that supply their own needs, amounting to 12.62 mgd.

Rural-Individual

Rural-individual water use in the basin amounts to about 0.9 mgd. Ground water accounts for an estimated 0.8 mgd, or 90 percent. The remainder is surface water. The estimated rural population served is about 15,000 persons. Few persons are rural residents because the economy of the basin is centered almost entirely in urbanized areas in and around Seattle.

WATER SUPPLIES

Municipal and industrial surface water supplies are obtained from the stems and tributaries of the Green and Cedar rivers in Cedar-Green Basin, the Tolt River in the Snohomish Basin to the north, and from numerous creeks. These sources also supply some rural-individual areas, but to a much lesser extent. Ground water supplies for municipal, industrial, and rural-individual use are plentiful in the lowland and mountain areas. The lowlands are generally west of a line through Hobart and Enumclaw. The present quantity of surface and ground supplies tapped for municipal, industrial, and rural-individual use averages about 165 mgd. Surface water furnishes 148 mgd of this total and ground water supplies furnish the remaining 17 mgd.

Municipal

Seattle utilizes the–Cedar River and the Tolt River watersheds for its municipal water supply. The Cedar River watershed, largest of the two, has an area of 143 square miles, extending from Landsburg on the west to the crest of the Cascade Mountains. It is about 25 miles long and 6 miles wide. In the center of the watershed lies Chester Morse Lake, which has been developed to provide 35,000 usable acre-feet of storage for hydroelectric generation and water supply (see Fig. 2-5).

TABLE 7-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd)			Ground water usage (mgd)		
		Average daily	Maximum monthly	Maximum daily	Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Seattle	887,420	91.90	130.00	253.00	---	---	---
Olympic View Water District	(13,500)	(1.20)	(2.36)	(3.00)	---	---	---
Edmonds	(8,200)	(0.50)	(0.75)	(1.00)	---	---	---
Kirkland	(10,000)	(0.85)	(1.02)	(1.20)	---	---	---
Bothell	(3,700)	(0.20)	(0.60)	(1.00)	---	---	---
Normandy Park	(1,640)	(0.12)	(0.24)	(0.37)	---	---	---
Tukwila	(1,600)	(0.23)	(0.25)	(0.27)	---	---	---
Duvall	(525)	(0.03)	(0.06)	(0.10)	---	---	---
Renton	38,175	---	---	---	4.10	6.30	8.50
Mountlake Terrace[a]	(13,400)	(0.80)	(1.20)	(3.20)	---	---	---
Auburn	17,100	1.90	2.60	3.25	1.10	1.40	1.75
Kent	10,457	---	---	---	2.47	2.81	3.15
Enumclaw	8,500	---	---	---	0.90	1.30	1.70
Redmond	3,497	---	---	---	0.33	0.97	1.60
Issaquah	2,368	---	---	---	0.35	0.43	0.50
Pacific	1,668	---	---	---	0.20	0.25	0.30
Black Diamond	1,035	---	---	---	0.18	0.22	0.25
Other rural community systems	55,000	0.08	0.20	0.28	4.12	7.53	11.30
Subtotal[b]	1,025,220	93.90	132.80	256.50	13.80	21.20	29.10
RURAL-INDIVIDUAL USE[c]	15,000	0.10	0.10	0.20	0.80	1.00	1.40
INDUSTRIAL USE							
Municipally supplied:							
Seattle:							
Food and kindred		3.82	4.00	4.27	---	---	---
Chemicals, metals, oils		9.20	10.30	12.21	---	---	---
Lumber and wood		1.31	1.60	1.80	---	---	---
Stone, clay, glass		0.03	0.03	0.04	---	---	---
Transportation		5.01	5.94	6.82	--	---	---
Renton:							
Food and kindred		0.01	0.01	0.01	0.01	0.02	0.03
Transportation		---	---	---	1.05	1.05	1.15
Kent:							
Food and kindred		---	---	---	0.13	0.26	0.39
Chemicals, metals, oils		---	---	---	0.25	0.28	0.30
Auburn:							
Food and kindred		0.02	0.02	0.03	0.01	0.01	0.02
Transportation		0.10	0.11	0.13	0.05	0.06	0.07
Self-supplied:							
Food and kindred		---	---	---	0.30	0.32	0.34
Chemicals, metals, oils		31.00	34.00	37.00	---	---	---
Lumber and wood		3.34	4.26	5.27	0.12	0.17	0.22
Stone, clay, glass		0.53	0.58	0.64	0.42	0.56	0.72
Subtotal		54.40	60.90	68.20	2.30	2.70	3.20
Total	1,040,220	148.40	193.80	325.00	16.90	24.90	33.70

[a] Served by Alderwood Water District which is served by Everett.

[b] Estimated population served exceeds the 1965 Task Force census population of 1,010,100 because of the rapidly increasing population growth experienced in the Seattle area in the past few years. Also, estimated served population for the city of Seattle includes some areas outside of the Cedar-Green Basin and numberous water distribution systems within the Cedar-Green Basin on a permanent and seasonal basis. Table 2-7 determined an "average rating" for this basin for 340 water systems: the population served by these water systems has been included in the nearest municipal systems since the municipality is often the water supplier for the smaller distribution system.

[c] Assumed relatively low figure of 15,000 persons because the Basin's economy and population is centered almost entirely in urban areas in and around Seattle. Estimated 90 percent of rural-individual use is supplied by ground water.

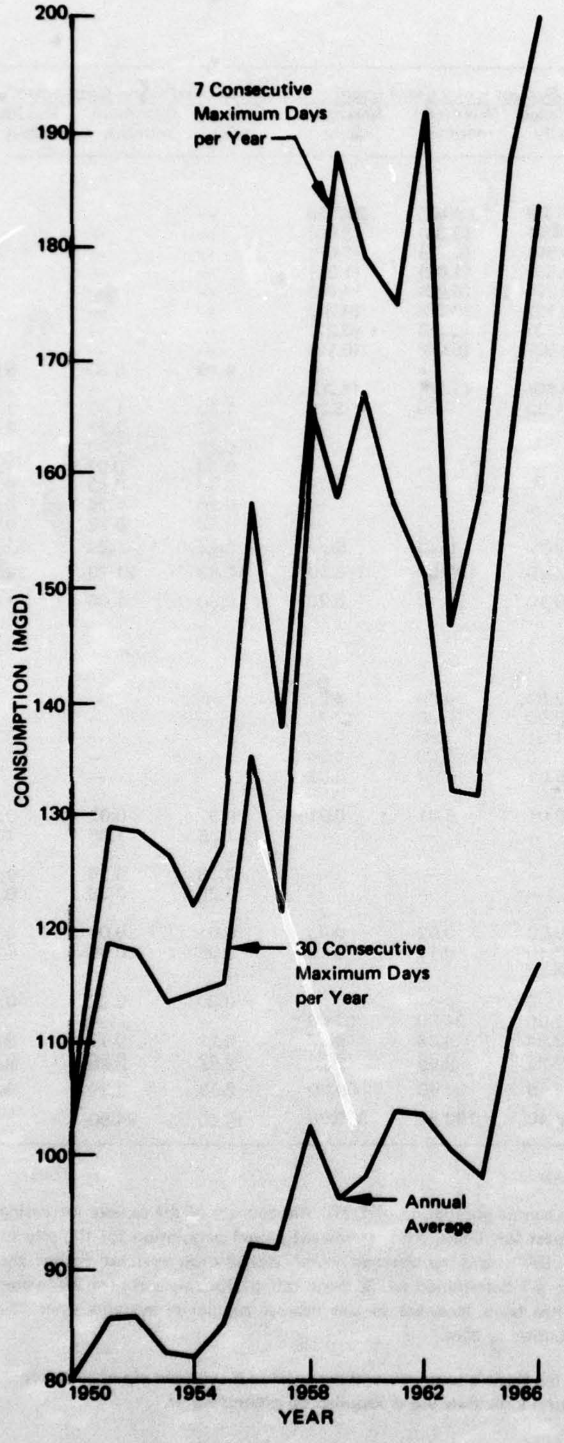


FIGURE 7-2. City of Seattle water consumption.

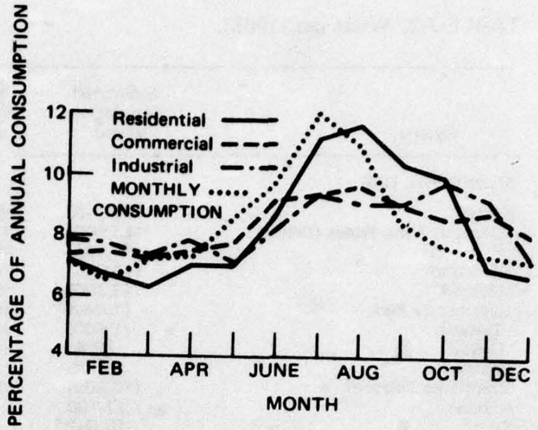


FIGURE 7-3. City of Seattle water use profile (1955-1965).

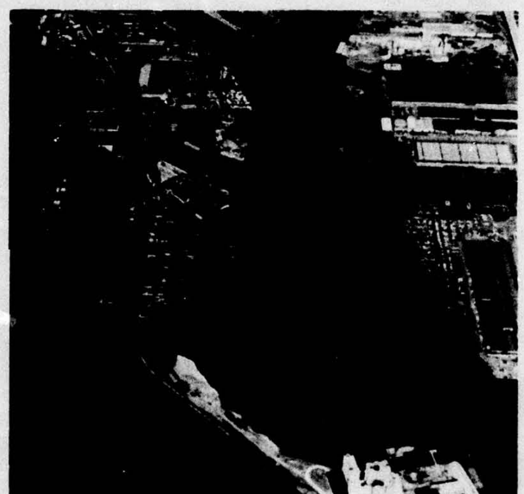


PHOTO 7-3. Industry along the Duwamish Waterway and other concentrated areas in Seattle use a large portion of the industrial water.

Almost three-fourths of the Cedar River watershed is owned by the city of Seattle; the remainder is owned by private interests and the federal government. Sustained-yield logging removes merchantable timber. A city power peaking generating plant is also located in the watershed, and has been in operation since 1904. Sanitary inspectors enforce sanitary regulations on all operations within the watershed and patrol the area to prevent trespass and contamination of the water supply.

A low-crest dam at Landsburg (28 miles from the city center) diverts a portion of the Cedar River waters through a screenhouse where it is chlorinated and diverted into pipelines that carry the water 10 miles to Lake Youngs. Formerly a natural lake, Lake Youngs was developed into an equalizing reservoir to serve as a settling basin when occasional periods of turbidity occur on the Cedar River. River water can also be diverted around the lake directly from the control works where the water is disinfected. From the Cedar River, 220 mgd can now be delivered through large gravity transmission mains to customers of the Seattle Water Department (Figure 7-8).

The Tolt River watershed in the Snohomish Basin, on the South Fork of the Tolt between the towns of Carnation and Skykomish, encompasses about 12,200 acres. An earth-fill dam impounds 57,900 acre-feet of water storage for municipal and industrial needs. The basin is about 3-1/2 miles long and 1/2 mile wide. Water is conveyed to a regulating basin 5 miles downstream from where it is piped to a receiving reservoir at Lake Forest Park, at the north end of Lake Wasnington, where the distribution system starts. The pipeline from the South Fork of the Tolt system can deliver 90 mgd to Seattle and suburban communities.

In the Tolt River watershed (photo 7-4), the Weyerhaeuser Company owns 53.8 percent of the land, the U.S. Department of Agriculture 28.9 percent, the city of Seattle 16.5 percent, and other interests 0.8 percent. The city of Seattle and the Weyerhaeuser Company have an agreement covering the operations in the watershed which gives the city the same degree of protection as exists on private lands in the Cedar River watershed. Therefore, the city need not purchase the private lands in the Tolt River area to protect the water quality.

The Cedar and South Tolt River systems currently supply Seattle average water needs of 134 mgd and peaks of 310 mgd. Further development of the North Fork of the Tolt River system could increase the peaking capability to 400 mgd. Further development on the Cedar River could increase peak water supply to 600 mgd.

The Seattle Water Dept. is one water system which currently designs and constructs for an option water supply category. They are now capable of supplying 2.0 gpm or 823 gpcd (see Figure 2-6). The WSDH option for this category is 16 gpm or 658 gpcd.

The city of Renton, south of Seattle at the southern end of Lake Washington, is the second largest water-using community in the basin. The city has a population of more than 38,000 persons. Several thousand additional persons employed by The Boeing Company work in the city each day. The Renton water supply system presently consists of five wells that distribute 4.1 mgd to the main parts of the city, with some small areas served by the adjacent Seattle water system.

In the Green River valley, the city of Auburn distributes 3 mgd to a population of 17,100 persons. Two springs and ground water from two wells are used. The nearby community of Kent, which has a population of 14,000 persons, uses 2.47 mgd obtained from two springs east of Kent. Water requirements in the Kent area are expected to increase considerably between 1965 and 2020.

The remaining cities and towns in the basin, except Mountlake Terrace, rely mainly on wells for their water supply. These systems serve populations ranging from 1,000 to 3,500 with 0.2 to 0.9 mgd. Mountlake Terrace, with an estimated population of more than 13,400 persons, is served by the Alderwood Water District, which in turn is provided water by the Everett municipal system. Numerous other rural community systems serve 4.2 mgd to about 55,000 persons.

Industrial

Water for industrial purposes is mostly municipally supplied. The Seattle water system supplies 34 percent of the needs of industries in the basin. Renton supplies industry with 1.07 mgd, Kent supplies 0.38 mgd, and Auburn 0.18 mgd. Several

PHOTO 7-4. The Tolt River watershed supplies water to Seattle from the Snohomish Basin.

industries in the Seattle area are self-supplied from surface sources for uses such as cooling. They use waters from Lake Washington, the Lake Union the Ship Canal, and Puget Sound. Other industries throughout the basin are self-supplied from wells, springs, and rivers.

Rural-Individual

An estimated 15,000 persons are supplied by rural-individual systems, and utilize 0.9 mgd. It is estimated that 90 percent of this supply is ground water and the remainder surface water. The rural-individual population is widely scattered, particularly in the eastern parts of the basin.

WATER RIGHTS

The Cedar-Green Basin has a total of 1,551 recorded water-rights; of these, 1,200 are surface and 331 are ground (1966-1967). Total recorded prime rights appropriated in this basin amount to 525 mgd, with applications, as of April 30, 1963, for 282 mgd additional - the cities of Seattle and Tacoma being the prime applicants.

Surface water for power generation, 141 mgd, is the largest use in the Cedar-Green Basin. Following are industrial, 111 mgd; municipal, 93 mgd; irrigation 65 mgd; single and community domestic supplies, 50 mgd; and fish propagation, 65 mgd. Seven storage rights have been perfected in this basin for a total annual quantity of 2,801 acre-feet. Most of this storage is associated with developments for wildlife and fish propagation use.

The city of Seattle obtains additional water for municipal use (205 mgd) and power generation (323 mgd) from the Cedar River under a claim to vested-rights.

Additional water is claimed by the Tacoma Water Department in the Green River Basin (130 MGD) under a 1906 priority right and (130 MGD) under a 1908 priority right.

Critical low flows of small streams in the basin and of the Green River have prompted the Departments of Fisheries and Game to close many sources to further consumptive appropriation and to impose low-flow restrictions on many diversions.

A total quantity of 191 mgd was appropriated under prime ground water permits and certificates as of September 30, 1966 and an additional quantity of 0.6 mgd was recorded under supplemental rights.

Ground water filings pending in the application stage would account for additional ground water development in this area amounting to about 12 mgd.

Individual, community and domestic supplies led the field of ground water used with 98 mgd; irrigation, 29 mgd; and municipal, 22 mgd.

Table 7-3 shows water rights in the Cedar-Green Basins.

TABLE 7-3. Consumptive water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	93.1	50.5	117.7
Ground water	22.0	98.0	20.1
Total[a]	115.1	148.5	137.8

[a]About 246 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

SURFACE WATER

Quantity Available

Resources of surface water abound in existing and potential, natural or developed, storage sites in the Cedar-Green Basin. However, the quantity available from existing resources is not inexhaustible, and future increases in water use from the Cedar River will reduce the beneficial inflow to Lake Washington by a corresponding amount. The prime surface water resources in the basin are the streams, artificial storage impoundments, and lakes.

Streams. The prime stream resources are those in the Green-Duwamish and Cedar River watersheds. Stream flow runoff data obtained in the Cedar-Green Basin indicate a range in mean annual runoff contribution from about 100 inches near the Cascade crest near the headwaters of the Cedar River to less than 20 inches near Seattle. The annual estimated average runoff for the basin during the 30-year period from

1931 through 1960 was about 36 inches, or 2,200,000 acre-feet. Runoff is measured at several discharge stations located throughout the basin. Refer to Appendix XIII for a map showing the location of these stations.

Runoff from the upper part of the Green River watershed has been measured since 1932 at a station near the community of Palmer. The 30-year period of record indicates a mean annual discharge of 1,080 cfs. The maximum annual runoff (1,500 cfs, or 139 percent of the 30-year mean) at this station occurred in 1959. The minimum annual discharge, in 1941, amounted to 47 percent of the mean (508 cfs). Extreme discharges of 27,800 cfs (maximum) and 81 cfs (minimum) have been recorded.

Stream flow records for the Cedar River date back to 1895, making it one of the longest periods of record for a stream in the Puget Sound Area. With the exception of two short periods, continuous measurements have been taken at a gaging station located near Landsburg. The data obtained represent the runoff from about the upper half of the Cedar River watershed and closely reflect natural runoff conditions. During the 1931 through 1960 period of record, the average annual discharge was 680 cfs. The highest annual discharge (940 cfs, or 138 percent of the 30-year mean) was recorded in 1934. The lowest discharge (340cfs) occurred in 1941 when the flow was only 50 percent of the mean. Extreme maximum and minimum dischares of 14,200 cfs and 83 cfs have been observed on the Cedar.

A stream gaging site at Bothell measures runoff from 88 percent of the Sammamish River watershed. During the 1939-1960 period of record, the average annual discharge was 367 cfs. The maximum recorded discharge occurred in 1965 and was 1,910 cfs (520 percent of the 21-year mean). The minimum discharge recorded during the 21-year period was 62 cfs (17 percent of the mean) in 1951. Stream flow of the Sammamish River depends highly on the amount of outflow from Lake Sammamish, which receives 40 percent of the total runoff in the watershed. The Cedar, Green, and Sammamish Rivers display runoff patterns similar to other rain and snow-fed streams. The highest flows occur during December and January, receding slightly as spring approaches, then merging into the less pronounced snowmelt runoff peak during April, May, and June. Base flows on the Cedar during the dry summer months are relatively high, in part because of the storage influence of Chester Morse Lake and sizable ground water contributions. The highest discharges of the Green River ususally result from winter rains. Pronounced low flows, reaching a minimum in August, reflect the absence of storage in glacial ice and meager contributions from ground water. Stream flow on the Sammamish is characterized by a series of sharp peaks from October through March and a summer base flow of about 200 cfs.

A low-flow frequency analysis has been made by the U.S. Geological Survey for 35 gaging stations in the basin (photo 7-5) based on an 18-year period of record from April 1, 1946, to March 31, 1964. The 7-day and 30-day flows that may be expected to occur at eight of these stations for recurrence intervals of 5, 10, and 20 years are shown in table 7-4. Use of low-flow data should take into account that: (1) the Cedar River at Landsburg is affected by regulation for power development at Chester Morse Lake and Masonry Pool; (2) records of the Cedar River made at Renton are affected by upstream regulation and diversion of the river for municipal use by Seattle; (3) recent channel improvements on the Sammamish River may have changed its low-flow characteristics; (4) records for the Green River below Palmer are affected by diversion to Tacoma and the operation of Howard A. Hanson Dam for flood control and conservation.

Dams and Impoundments. There are three dams in the Basin. These are the Howard A. Hanson Dam on the upper Green River and Masonry Dam at Masonry Pool adjacent to Chester Morse Lake on the upper Cedar River. A crib dam is also located at Chester Morse Lake (upper Cedar River).

PHOTO 7-5. Watershed protection keeps bacterial count low in the upper Green River.

TABLE 7-4. Low-flow frequency.

Station	Recurrence interval (years)	7-day low flow (cfs)	30-day low flow (cfs)
Green River near Lester	5	30.0	34.0
	10	27.0	30.0
	20	24.7	26.5
Newaukum Creek near Black Diamond	5	13.0	14.5
	10	11.3	12.7
	20	10.0	11.1
Big Soos Creek near Auburn	5	25.0	26.5
	10	22.0	23.5
	20	20.0	21.0
Green River at Tukwila	5	168.0	185.0
	10	140.0	155.0
	20	120.0	130.0
Cedar River near Landsburg	5	210.0	235.0
	10	184.0	210.0
	20	170.0	190.0
Cedar River at Renton	5	56.0	75.0
	10	40.0	52.0
	20	29.0	36.0
Issaquah Creek near Issaquah	5	12.6	14.0
	10	11.7	12.7
	20	11.0	11.7
Sammamish River at Bothell	5	78.0	83.0
	10	72.0	75.0
	20	66.0	70.0

The Howard A. Hanson Reservoir has a maximum storage of 106,000 acre-feet and provides 106,000 acre-feet of active storage for municipal and industrial water supply and conservation. Maximum storage is not retained in Howard A. Hanson reservoir, but is dissipated as soon after a flood as possible to provide storage capacity in the event of a second flood. During low-flow periods, discharge below the dam is augmented so that about 100 cfs is maintained in the lower reaches for fishery enhancement.

Chester Morse Lake is a natural lake that has been developed to provide 56,000 acre-feet of storage for hydroelectric power and water supply. The Masonry Pool reservoir, located about 2 miles downstream from Chester Morse Lake, has a capacity of 4,000 acre-feet. In 1900, storage in Chester Morse Lake was increased by the construction of a crib dam 15 feet high. Masonry Dam, completed in 1918 to a height of 120 feet, was constructed to inundate the crib dam and provide increased storage for power generation and municipal supply. An immense earth slide and washout near the right abutment occurred shortly after construction of the dam. Since this failure, the level of the Masonry Pool has been maintained at an elevation of about 1,555 feet, which is the crest elevation of the crib dam. A high rate of seepage occurs from the reservoir when higher water levels are attained, creating conditions that could result in another failure.

The city diverts municipal water from the Cedar River near Landsburg into storage in Lake Youngs. The lake has a reservoir area of 700 acres and provides 11,000 acre-feet of off-stream storage for the city of Seattle. The lake is used primarily as a storage reservoir, and up to 150 mgd is drawn from it when the river water becomes turbid, at which time no river water is diverted.

Lakes. The most notable fresh-water lake resource in the basin is the Lake Sammamish-Lake Washington chain, connected by the 14-mile-long Sammamish River. About 607 square miles of surface area drain into Lake Washington through the Sammamish River at the north and the Cedar River at the south. The Lake Washington Ship Canal complex, 6-1/2 miles long with a minimum depth of 30 feet, connects Lake Washington to Shilshole Bay and Puget Sound. Ideally, the Chittenden Locks maintain the water level in Lake Washington and the ship canal complex between 20 and 21.85 feet above mean low tide on Puget Sound. Lowering to below 20 feet is sometimes necessary during periods of low inflow to provide enough water to operate the locks.

The minimum depth of the canal is some 10 feet below the mean low tide level. Therefore, operation of the locks, particularly at high tides, permits some upstream flow of salt water from Shilshole Bay. Part of the lock system consists of a huge sump in Salmon Bay, just above the locks. Most of the cold, dense sea water settles into the sump and is pumped back to the downstream side of the locks. During periods of low inflow into Lake Washington, from April to November, this system cannot remove all the salt water, and a layer of cold sea water penetrates along the bottom of the canal toward Lake Washington. To prevent permanent salination of the lake and destruction of fresh-water plant and animal life, salt content is monitored at the Montlake Bridge. When salinity reaches 10 mg/l, the upstream syphon intake in the ship canal is opened to flush the salt water back toward the sound below the locks.

Quality

High-quality surface water is available at selected points in the Cedar-Green Basin, as shown in table 7-5. The major rivers and streams flow from isolated and protected country. However, industrial development and an increasing population, with their accompanying waste disposal to surface waters, have caused the water quality of some lakes, downstream sections of major streams, and other water courses to deteriorate.

Data in table 7-5 were gathered from 10 monitoring stations since about 1959.

Physical The maximum summer temperature of the Green River at Auburn, 24.2°C (75.6°F), has one of the highest recorded stream temperatures in the Puget Sound Area. Other high temperatures have occurred in the Sammamish River at Bothell, 23.6°C (74.5°F), and in the Cedar River at Renton, 22.8°C (73.0°F). The Lake Washington Ship Canal water has attained a high of over 20.4°C (69°F). Summertime temperatures in other streams in the Basin are considerably cooler; no stream exceeds 18.5°C (65.3°F).

Streamborne sediment is not a serious problem in the upper parts of rivers in the basin, but it is a problem in their lower reaches. A dense cover of vegetation on most slopes prevents excessive soil erosion. Streams in the Cedar River watershed transport only small amounts of sediment, with suspended-sediment concentrations of less than 20 mg/l. Sediment data collected daily on the upper Green River from 1951 to 1955 showed suspended-sediment concentrations ranging from 1 to 1,350 mg/l. On the lower Green River at Tukwila, the maximum concentration was 1,590 mg/l.

Turbidity is generally high in the major streams except the Cedar River. Maximum turbidity observed in Issaquah Creek was 350 JTU, the highest recorded turbidity in the Basin. The Sammamish River at Bothell showed a maximum of 120 JTU. Maximum turbidity on the Duwamish River at Tukwila was 70 JTU, less than Issaquah Creek or the Sammamish River. Smaller streams have low turbidities, generally less than 6.0 JTU, and seldom surpassing 25 JTU.

Chemical. The chemical quality of surface water in the Cedar-Green Basin is excellent, and the water is acceptable for nearly all uses with little treatment. Water from most streams and lakes is chemically soft, low in dissolved solids, and high in dissolved oxygen concentrations. The greatest concentrations of dissolved solids occur in the Duwamish River near Tukwila and in the Lake Washington Ship Canal.

Significant amounts of iron occur in some stream sections. Iron concentrations in the Sammamish River at Bothell average 0.5 mg/l; a maximum concentration of 2.4 mg/l has been recorded. In Issaquah Creek, the average is 0.7 mg/l and the maximum 2.6 mg/l. In the Duwamish River at Tukwila, the average iron content is 0.6 mg/l and the maximum 1.7 mg/l.

Dissolved oxygen values in Table 7-5 indicate that most fresh water in the basin contains adequate oxygen to maintain aquatic life. However, the estuarial reach of the Duwamish River from Tukwila downstream to the mouth does have at times, a dissolved-oxygen content of less than 5 mg/l caused, in part, by changes from a free-flowing stream to a fairly quiescent tidal condition.

The lower Duwamish River has been the subject of study by various agencies since the city of Seattle began its study of dissolved oxygen in the river during the fall of 1948. In August 1949, the dissolved-oxygen content in the bottom water was 3.7 mg/l and in the surface layer it measured 6.1 mg/l. As part of a comprehensive water quality program begun in 1961, Metro (the municipality of metropolitan Seattle) has studied extensively the physical, chemical, and biological characteristics of the lower Green River and the Duwamish Waterway. A cooperative monitoring program has been maintained since 1964 by Metro and the U.S. Geological Survey. Biological and nutrient sampling of the Green-Duwamish River is conducted monthly during the winter and weekly throughout the remainder of the year. Routine sampling in August 1963 showed that the bottom waters in the Duwamish Waterway lacked adequate amounts of dissolved oxygen at times zero DO was recorded to maintain aquatic life for a prolonged period. Further sampling during the critical summer period revealed a month-by-month degeneration in oxygen concentration. Dissolved oxygen decreased from 5.2 mg/l in July to 3.1 mg/l in September.

Studies in Lake Union and the Lake Washington Ship Canal relating to salt water intrusion and dissolved oxygen depletion were started in 1964 and continued in 1966. Records show a noticeable decrease in salt water intrusion from Puget Sound into the canal since 1960. Little intrusion was detected beyond Lake Union in 1966. Dissolved oxygen concentrations are zero in the bottom waters of Lake Union. Although sewers that had been

TABLE 7-5. Surface water quality

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate	Coliform (MPN)
		mg/l												mg/l									mg/l		mg/l		
GREEN RIVER NEAR PALMER																			JULY 1959 THROUGH JULY 1961								
Maximum	10,900	46	6.6	1.4	3.3	0.5	32	0	3.8	1.5	0.2	0.9	62	0.06	—	17.0	0.58	0.09	7.5	10	—	18.0	13.1	104	22	2	430
Mean	—	37	5.1	0.6	2.5	0.2	22	0	2.1	1.0	0.1	0.2	44	0.02	—	13.5	0.13	0.03	—	—	—	8.8	11.2	100	15	0	114
Minimum	156	28	3.4	0.1	2.0	0.0	13	0	1.4	0.5	0.0	0.0	33	0.00	—	11.0	0.00	0.00	6.2	0	—	2.0	9.4	90	10	0	0
Number	21	21	21	21	19	19	21	4	21	21	20	21	21	18	—	21	20	4	20	21	—	16	17	16	21	21	17
GREEN RIVER AT PURIFICATION PLANT NEAR PALMER																			OCTOBER 1931 AND OCTOBER 1948								
Maximum	—	39	5.2	1.2	6.9	0.6	29	—	3.2	6.3	0.0	0.2	—	—	—	23.0	0.05	—	7.4	—	—	—	—	—	18	0	—
Mean	—	39	5.1	1.2	4.8	0.6	25	—	2.6	3.9	0.0	0.1	—	—	—	18.5	0.02	—	—	—	—	—	—	—	18	0	—
Minimum	—	39	5.0	1.2	2.7	0.6	21	—	2.0	1.6	0.0	0.0	—	—	—	14.0	0.00	—	7.4	—	—	—	—	—	17	0	—
Number	—	1	2	2	2	1	2	—	2	2	1	2	—	—	—	2	2	—	1	—	—	—	—	—	2	1	—
GREEN RIVER NEAR AUBURN																			JULY 1959 THROUGH FEBRUARY 1966								
Maximum	4,600	71	11.0	3.1	6.0	1.0	50	0	6.4	3.8	0.3	1.9	103	0.13	—	16.0	1.20	0.03	7.9	15	40	24.2	14.1	132	39	0	24,000
Mean	—	51	7.1	1.6	3.6	0.5	32	0	3.8	1.7	0.1	0.7	67	0.03	—	13.2	0.24	0.01	—	—	—	10.1	11.1	101	24	0	1,225
Minimum	172	30	4.0	0.5	2.2	0.0	20	0	2.0	0.0	0.0	0.0	38	0.00	—	9.6	0.00	0.00	6.2	0	0	3.5	8.3	81	14	0	0
Number	63	84	84	84	84	84	84	33	84	84	84	84	84	73	—	84	71	13	84	83	45	87	88	87	84	84	86
GREEN RIVER AT TUKWILLA																			OCTOBER 1962 THROUGH APRIL 1966								
Maximum	—	116	20.0	20.0	16.0	1.7	68	0	9.8	19.0	0.2	4.5	954	0.89	—	18.0	1.70	0.09	7.6	30	70	20.0	12.7	112	133	78	240,000
Mean	—	72	9.0	3.0	7.4	1.0	41	0	5.7	6.8	0.1	2.0	121	0.21	—	14.5	0.58	0.03	—	—	—	10.6	9.7	89	35	2	17,289
Minimum	—	34	4.5	0.5	2.7	0.1	22	0	2.0	1.2	0.0	0.4	46	0.05	—	11.0	0.29	0.01	6.6	0	5	4.5	6.2	66	16	0	230
Number	—	47	48	48	47	47	48	37	47	47	47	47	48	35	—	48	34	7	48	47	36	50	51	50	48	48	50
CEDAR RIVER AT RENTON																			JULY 1959 THROUGH MARCH 1966								
Maximum	1,920	77	12.0	3.7	5.0	0.9	58	0	6.0	2.2	0.1	1.9	112	0.28	—	15.0	1.30	0.06	7.9	10	25	22.8	12.5	118	46	0	4,600
Mean	—	44	7.3	1.4	2.6	0.4	31	0	3.1	1.2	0.1	0.5	62	0.03	—	11.3	0.15	0.02	—	—	—	10.6	10.8	100	24	0	420
Minimum	67	34	5.0	0.6	1.6	0.0	22	0	1.6	0.5	0.0	0.0	46	0.00	—	8.8	0.00	0.00	6.9	0	0	4.1	7.6	77	16	0	0
Number	39	46	46	46	46	46	46	19	46	46	46	46	46	43	—	46	43	13	46	46	16	50	51	50	46	46	50
CEDAR RIVER NEAR LANDSBURG																			JULY 1959 THROUGH AUGUST 1962								
Maximum	1,800	51	11.0	1.6	2.2	0.5	39	0	4.0	2.2	0.2	0.6	73	0.04	—	12.0	0.24	0.01	7.8	5	0	14.5	12.5	106	31	2	230
Mean	—	39	7.1	0.8	1.7	0.3	27	0	2.0	1.0	0.0	0.2	53	0.01	—	10.1	0.05	0.00	—	—	—	9.3	11.1	101	21	0	34
Minimum	335	27	5.0	0.0	1.2	0.0	18	0	0.0	0.5	0.0	0.0	37	0.00	—	4.0	0.00	0.00	7.0	0	0	5.3	9.7	93	14	0	0
Number	21	23	23	23	21	21	23	9	23	23	22	23	21	21	—	23	22	4	22	22	4	20	21	20	23	22	21
SAMMAMISH RIVER AT BOTHELL																			JULY 1959 THROUGH MARCH 1956								
Maximum	1,070	100	12.0	6.6	7.2	2.1	62	0	16.0	4.5	0.5	6.3	145	0.44	—	17.0	2.40	0.02	7.4	40	120	23.6	12.5	119	55	15	11,000
Mean	—	71	9.2	4.0	5.2	1.2	45	0	9.0	3.0	0.1	1.8	105	0.10	—	10.6	0.49	0.01	—	—	—	12.2	9.9	95	39	3	1,788
Minimum	8	57	7.5	2.5	3.5	0.7	32	0	6.6	1.0	0.0	0.3	82	0.00	—	5.1	0.08	0.00	6.6	5	5	5.0	7.3	80	31	0	91
Number	43	53	53	53	53	53	53	14	53	53	53	53	53	50	—	53	50	11	53	53	22	57	57	57	53	53	56
ISSAQUAH CREEK NEAR ISSAQUAH																			NOVEMBER 1964 THROUGH APRIL 1966								
Maximum	—	94	13.0	5.1	7.6	1.2	68	0	12.0	5.0	0.2	6.2	138	0.99	—	20.0	2.60	0.04	7.2	20	350	13.3	12.2	105	53	6	24,000
Mean	—	73	9.7	3.6	5.6	0.8	46	0	7.3	2.7	0.1	3.1	104	0.41	—	15.9	0.73	0.03	—	—	—	9.2	10.7	96	39	2	10,626
Minimum	—	52	5.6	2.2	3.5	0.4	23	0	5.4	1.8	0.1	1.5	67	0.08	—	12.0	0.06	0.02	6.3	5	5	5.8	8.9	85	23	0	36
Number	—	22	22	22	22	22	22	22	22	22	22	22	22	11	—	22	11	2	22	—	11	9	9	9	22	22	9
BIG SOOS CREEK ABOVE HATCHERY NEAR AUBURN																			OCTOBER 1962 THROUGH APRIL 1966								
Maximum	484	81	12.0	4.6	6.3	1.8	58	0	12.0	3.5	0.5	3.7	115	0.19	—	20.0	0.46	0.05	7.7	60	10	15.6	12.8	121	45	6	24,000
Mean	—	71	9.5	3.4	5.4	1.0	45	0	8.6	2.2	0.1	1.7	101	0.06	—	14.6	0.14	0.03	—	—	—	9.8	11.0	100	38	1	1,130
Minimum	20	62	7.5	1.2	4.4	0.5	31	0	5.8	1.0	0.0	0.6	88	0.02	—	11.0	0.03	0.00	6.8	5	0	3.6	9.4	88	30	0	0
Number	24	46	45	45	45	45	45	33	45	45	45	46	46	34	—	45	34	8	46	46	33	49	49	49	46	46	48
LAKE WASHINGTON SHIP CANAL AT SEATTLE																			OCTOBER 1964 THROUGH SEPT 1965								
Maximum	—	333	14.0	14.0	87.0	4.6	48	0	28.0	152.0	0.1	5.9	650	0.29	—	7.9	0.25	0.10	7.5	5	25	20.4	12.5	123	92	53	4,600
Mean	—	174	10.3	7.5	39.9	2.4	41	0	16.3	66.9	0.1	2.3	330	0.17	—	4.4	0.13	0.07	—	—	—	12.6	9.7	93	57	23	1,866
Minimum	—	62	8.4	3.4	6.4	1.1	36	0	8.0	6.5	0.0	1.2	108	0.13	—	1.1	0.08	0.04	6.8	5	0	2.5	7.5	73	35	5	36
Number	—	12	12	12	12	12	12	12	12	12	12	12	12	12	—	12	12	2	12	12	12	12	12	12	12	12	12

emptying into Lake Union have been intercepted by the Metro system, bottom deposits and storm water overflows continue to degrade Lake Union water quality.

Water quality in the basin is also affected by the introduction of toxicants, especially by industries located along the Green-Duwamish River. Although data are not available, it is known that concentrations of toxic wastes have been high enough at times to be lethal to fish and aquatic life. In the case of the Duwamish, essentially all industries discharge wastes containing toxicants, but their concentrations are required to be within established standards. Careless spills and dumps in the past, however, have allowed highly toxic materials to reach the waterway, and these were extremely detrimental to the aquatic life of the river. Cyanides, chromates, acid pickling liquor, oils, grease, sodium hydroxide, phenols, and pentachlorophenols are some of the wastes that enter the river.

Bacteriological. Sanitary quality in the lower reaches of major streams in the basin has been a problem for many years. The presence of a high number of fecal coliform organisms in water samples taken at the stations, as shown in table 7-6, indicates possibly dangerous pollution in some areas. The Green River above Auburn (figure 7-8) is bacteriologically satisfactory; the MPN range near Palmer was only 0 to 430. Conditions become worse downstream. At Auburn, the MPN range was 0 to 24,000. On Big Soos Creek, a tributary to the Green River, the MPN range was 0 to 24,000. MPN values range from 230 to 240,000 on the Duwamish River at Tukwila.

The bacteriological quality of the Cedar River is excellent above Landsburg, where 88 percent of the MPN recorded was less than 240. Downstream at Renton, the MPN range was 0 to 4,600.

On the Sammamish River at Bothell, MPN values are usually less than 1,000, but a high of 11,000 has been recorded. The Lake Washington Ship Canal showed MPN values ranging from 36 to 4,600. Issaquah Creek, which flows into Lake Sammamish, has an average coliform count in excess of 11,000 MPN and an MPN range of 36 to 24,000.

In the past, a few of the larger lakes have been subject to uncontrolled water pollution. Until a few years ago, Green Lake was an eutrophic body of water plagued by heavy blooms of blue- green algae during the warmer months. Use of the lake was impeded by seasonal algal blooms, sewer overflows, the routing of storm water into the lake, littoral vegetation, mud shoals, waterfowl droppings, and outbreaks of swimmers itch. After studying the situation, the Seattle Park Department instituted a program to improve the lake. Large amounts of nutrient- poor city water were added to dilute the lake, and dredging and shoreline improvements were undertaken. Since 1962, the lake has been flushed about seven times. This has decreased the quantity of algae, improved the transparency of the water, and virtually eliminated one species of blue-green algae. These remedial actions have saved Green Lake from complete degradation.

At the same time, Lake Washington was becoming opaque with scum and filth. Excessive amounts of raw domestic sewage was converting its oligotrophic character to a condition of eutrophy. In 1960, Metro started a 10-year program with one objective to eliminate waste inflow to Lake Washington. To date, Metro has greatly reduced the contamination of Lake Washington, and the lake is regaining its sparkling blue sheen and oligotrophic condition.

A limnological investigation of water quality in Lake Sammamish is presently being conducted by Metro to determine conditions and devise means to prevent further eutrophication. The study so far indicates that the lake is in the early stages of eutrophication and is possibly more degraded than Lake Washington was in 1950. Twelve stations were established on the lake to collect data on water quality. A substantial quantity of nutrients are being contributed by Issaquah Creek, Tibbetts Creek, and several minor tributary streams. The blue-green algae population of Lake Sammamish is a typical indication that the lake is undergoing eutrophication. In 1964, 20 percent of the samples at three stations exceeded 240 MPN. A year later, only one station had 20 percent of samples over 240 MPN, but this station was located in an area of maximum recreation usage. More than 5 percent of samples taken from two other stations exceeded 2,400 MPN.

Information on temperature, transparency, nutrients, dissolved oxygen, phytoplankton, and zooplankton populations, primary productivity, and bacteriological data are not available for other freshwater lakes in the basin. Probably, population increases and encroaching suburban developments will cause other lakes to deteriorate at an increasing rate in the future unless protective measures are taken during land development.

GROUND WATER

Quantity Available

Ground water supplies are plentiful in many places in lowland and mountain areas of the Cedar-Green Basin. The most important aquifers occur in the lowlands in sedimentary deposits of the Quaternary Age. These sediments are mainly till, recessional outwash, alluvium, and mudflow deposits. The uplands are covered principally by till.

The alluvium, which occurs mainly on flood plains of the Sammamish, Cedar, and Green Rivers, is composed principally of sand and gravel. Fine sand, silt, and clay predominate in the Green River valley north of Auburn. The water table in the alluvium is generally about the same level as the river. Deeper alluvial aquifers in the lower Green River valley are confined under artesian pressure. Mudflow deposits are exposed on the uplands east of Auburn and south of the Green River. They serve as a confining layer for underlying artesian aquifers.

Sediments older than till are exposed along some margins of the uplands, especially along Puget Sound and the lower Green River valley. These older sediments include sand and gravel aquifers that contain fresh water at most places. Consolidated rocks of pre-Quaternary Age usually do not contain significant aquifers.

Precipitation, primarily rainfall, recharges the lowland aquifers. These aquifers are estimated to receive about 110,000 acre-feet of recharge in an average year. The natural discharge of ground water is primarily into the lower drainages of the Green, Cedar, and Sammamish Rivers and Lakes Washington and Sammamish.

Quality

Most aquifers in the basin furnish ground water of excellent quality that is acceptable for nearly all uses. Concentration of dissolved solids is usually less than 200 mg/l in the shallower aquifers, and somewhat greater–up to 500 mg/l – in deeper aquifers. Hardness of the ground water is generally less than 120 mg/l. Highly mineralized water occurs in some aquifers adjacent to Puget Sound. Silica content averages about 30 mg/l in waters containing less than 200 mg/l of dissolved solids. Brackish water occurs only locally in the deeper aquifers. Some deep aquifers in the southern part of the basin commonly yield water containing more than 50 mg/l of sodium. Table 7-6 contains ground water quality data for selected wells in the basin.

PRESENT AND FUTURE NEEDS

The Cedar-Green Basin will continue to be the center of population and economic growth in the Puget Sound Area through the turn of the century. The Seattle Water Department has in current use, and presently under development, watersheds on the South Fork of the Tolt River and the Cedar River adequate to meet the projected municipal and industrial water needs to the year 2007. Figure 7-8 shows the water requirements from 1922 to the present, projected needs through 2020, and the supply sources.

The Green River is the principal source of municipal and industrial water for the city of Tacoma, and consequently cannot be considered a reserve source of supply for increased future water needs the Cedar-Green Basin.

Vashon Island is expected to grow more slowly than the remainder of the basin, primarily because of restricted access to the mainland and the lack of adequate water reserves.

Several communities in the south portion of the basin, notably south Kent and Auburn- Federal Way, are projected to have the largest single increase in population. These communities, mostly served by individual and small community systems, already have an inadequate supply of ground water and are too far south to be served economically from the Lake Youngs supply. At present, these communities can be served from the northeast service area of the Tacoma water system.

PROJECTED POPULATION GROWTH

The 1965 Cedar-Green Basin population (1,040,200) is projected to increase to 1,479,000 (42 percent) by 1980, to 2,375,700 (130 percent) by 2000, and to 3,816,300 (267 percent) by 2020. (See figure 7-4.) Expansion will be mostly to the east, including most of the Snoqualmie River Valley lying south of Carnation, and south of the Cedar River

TABLE 7-6. Ground water quality.

Owner	Location code[a]	Date	Temperature (°F)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids	Hardness ($CaCO_3$)	Specific conductance (µmho)	pH
				Cations (mg/l)											
King County Water Dist. No. 64	21/4-5Q2	12/18/59	50	19	4.4	14	5.3	5.8	2.6	0.2	0.09	102	57	157	7.6
King County Water Dist. No. 19	23/3-29Qs	3/3/61	47	28	0.01[d]	10	8.6	6.0	1.2	10.0	0.07	116	60	158	7.3
The Boeing Company	23/4-4A1	4/9/54	56	25	0.14			314	8.4	1.0		872		1600	
City of Renton	23/5-17F1	6/23/60	55	14	0.00	12	3.5	4.0	0.5	0.8	0.02	74	44	110	6.9
King County School Dist. No. 400	24/4-25R1	4/11/58	62	23	0.41	10	10	6.0	4.2	0.1		104	66	156	7.7
King County Water Dist. No. 82	24/6-4N1	4/3/58	48	34	1.0[d]	10	4.6	4.2	3.3	3.3		96	44	106	7.2
Providence Heights College No. 2	24/6-9J1	10/6/60		25	0.20	7.0	3.8	3.9	0.8	0.7	0.14	68	33	85	7.3
City of Issaquah	24/6-27Q1	8/20/51	50	17	0.07	22	3.5	7.4	1.8	0.1		109	69	162	8.0
City of Redmond	25/5-12C1	3/24/59	40	23	0.06	10	4.7	4.9	1.1	5.6		82	44	116	7.3
Bothell Water District	26/5-5E1	8/24/51		47	0.03	21	8.4	8.6	4.0	0.7		158	87	201	7.1

[a] Location code is the legal description of the site of the well or, in some cases, spring. For example, 27/2-25N2 indicates township 27, range 2 east (range west would be indicated by 2W), section 25, 40-acre plot N, and the second well (2) in that plot (a letter s after the numeral would indicate a spring).

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

[d] Total iron concentration. All values not noted represent iron in solution at the time the sample was collected.

Source: GROUND WATER IN WASHINGTON, ITS CHEMICAL AND PHYSICAL QUALITY, Water Supply Bulletin No. 24, Washington State Department of Conservation.

watershed western boundary. The great increase in population in the south Kent, Auburn, and Federal Way areas will result in a lower percentage of the total basin population being served by the Seattle Water Department. Tacoma will probably serve this rapid growth area.

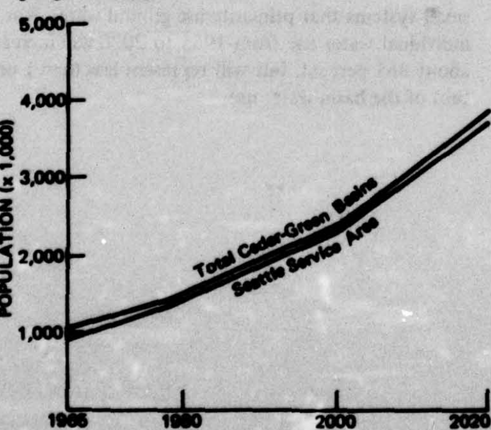


FIGURE 7-4. Projected population growth.

PROJECTED INDUSTRIAL GROWTH

Production growth as measured by increased value added is expected to more than triple by the year 2020 as shown in Figure 7-5. The primary industrial force creating this growth is transportation-oriented industry (chiefly The Boeing Company and Pacific Car and Foundry Company), which is predicted to grow steadily to the year 2000, after which it is expected to accelerate through 2020.

Until recently, Lake Washington was suffering a rapid increase in eutrophic conditions caused by inflow of domestic sewage. Present interception and treatment of this waste has reversed the action, improving the condition of Lake Washington, but a reasonable amount of fresh water inflow must be continued, or even increased, to prevent future water quality degradation. The Cedar River is the chief source of fresh water inflow for the lake. Any increase in water diverted from the Cedar River for fresh water supplies will reduce the amount of inflow to the lake. This condition rigidly restricts the amount of water that can be diverted from the Cedar River if water quality is to be maintained or improved in Lake Washington.

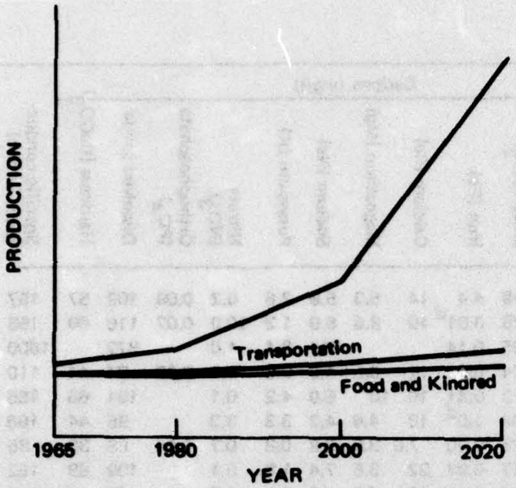


FIGURE 7-5. Relative production growth for major water-using industries and transportation.

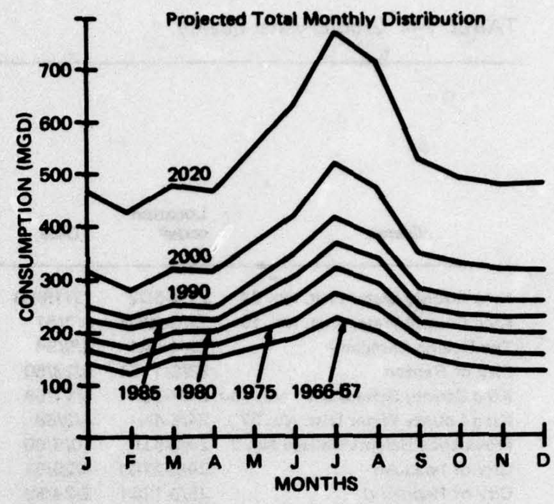


FIGURE 7-6. Seattle Water Department.

PROJECTED WATER REQUIREMENTS

Demands for fresh water generated within the basin have been estimatd in detail. Table 7-7, 7-8, and 7-9 show projected water needs for the years 1980, 2000 and 2020, respectively. Table 7-10 is a summary of water requirements for these years by use category. Figure 7-6 shows Seattle projected distribution.

Municipal

Annual average per capita municipal water use is projected to range from 112 gpd at present to about 177 gpd in 1980, 151 gpd in 2000, and 148 gpd in 2020. Seattle gpd's are based on figures in "A forecast of water supply and demand to the year 2020" by the city of Seattle Water Department.

Industrial

Industrial water use will continue to account for a lesser amount than municipal use, as it does now. Estimates indicate that industrial requirements will increase by 503 mgd in 2020 over as it does now. Estimated indicate that idustrial requirements will increase by 503 mgd in 2020 over those of 1965. The single major industrial use will be in the transportation segment of the economy.

Rural-Individual

All significant information indicates that the industrial, commercial, and municipal water consumption will account for the major growth of water use, and that they will increasingly assimilate the small systems that primarily use ground water. Rural-individual water use from 1965 to 2020 will increase about 365 percent, but will represent less than 1 percent of the basin water use.

TABLE 7-7. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Seattle	1,271,200	222.00	340.00	—	—
Renton	55,000	—	—	10.40	14.60
Auburn	30,000	3.80	5.30	1.90	2.70
Kent	20,000	—	—	3.80	5.30
Enumclaw, Redmond, Issaquah, Black Diamond, Pacific, and other rural community systems	85,000	—	—	16.00	23.00
Subtotal	1,461,200	225.80	345.30	32.10	45.60
RURAL-INDIVIDUAL USE	17,800	—	—	1.20[a]	1.80
INDUSTRIAL USE					
Municipally supplied:					
Seattle:					
Food and kindred	—	5.70	8.60[b]	—	—
Chemicals, metals, oils	—	15.00	16.50[b]	—	—
Lumber and wood	—	1.00	1.00	—	—
Stone, clay, glass	—	0.05	0.05	—	—
Transportation	—	13.30	14.70[c]	—	—
Renton:					
Food and kindred	—	0.02	0.03[b]	0.02	0.03[b]
Transportation	—	—	—	2.80	3.10[c]
Kent:					
Food and kindred	—	—	—	0.20	0.30[b]
Chemicals, metals, oils	—	—	—	0.41	0.45[c]
Auburn:					
Food and kindred	—	0.03	0.04[b]	0.02	0.03[b]
Transportation	—	0.26	0.30[c]	0.13	0.14[c]
Self-supplied:					
Food and kindred	—	—	—	0.45	0.68[b]
Chemicals, metals, oils	—	50.50	55.50[c]	—	—
Lumber and wood	—	2.70	2.70	0.10	0.10
Stone, clay, glass	—	1.00	1.00	0.80	0.80
Subtotal	—	89.56	100.42	4.93	5.63
Total[d]	1,479,000	315.40	445.70	38.20	53.00

[a]Based on 70 gpcd and 100 percent of rural-individual population served by ground water.

[b]150 percent of average.

[c]110 percent of average.

[d]Figures are rounded.

TABLE 7-8. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly
MUNICIPAL USE					
Seattle	2,079,900	297.00	612.00	---	---
Renton	100,000	---	---	21.00	29.00
Auburn	60,000	8.40	11.80	4.20	5.90
Kent	40,000	---	---	8.40	11.80
Enumclaw, Redmond, Issaquah, Black Diamond, Pacific, and other rural community systems	72,000	---	---	15.00	21.00
Subtotal	2,351,900	305.40	623.80	48.60	67.70
RURAL-INDIVIDUAL USE	23,800	---	---	2.10[a]	3.00
INDUSTRIAL USE					
Municipally supplied:					
Seattle:					
Food and kindred	---	11.50	17.20[b]	---	---
Chemicals, metals, oils	---	35.40	39.00[c]	---	---
Lumber and wood	---	0.80	0.80	---	---
Stone, clay, glass	---	0.10	0.10	---	---
Transportation	---	42.00	46.00[c]	---	---
Renton:					
Food and kindred	---	0.03	0.04[b]	0.03	0.04[b]
Transportation	---	---	---	8.90	9.80[c]
Kent:					
Food and kindred	---	---	---	0.40	0.60[b]
Chemicals, metals, oils	---	---	---	0.97	1.10[c]
Auburn:					
Food and kindred	---	0.06	0.09[b]	0.03	0.04[b]
Transportation	---	0.80	0.90[c]	0.40	0.40[c]
Self-supplied:					
Food and kindred	---	---	---	0.90	1.30[b]
Chemicals, metals, oils	---	119.00	131.00[c]	---	---
Lumber and wood	---	2.20	2.20	0.10	0.10
Stone, clay, glass	---	2.30	2.30	1.80	1.80
Subtotal	---	214.19	239.63	13.53	15.18
Total[d]	2,376,000	519.60	863.40	64.30	85.90

[a]Based on 90 gpcd and 100 percent of rural-individual population served by ground water.

[b]150 percent of average.

[c]110 percent of average.

[d]Figures are rounded.

TABLE 7-9. Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Seattle	3,419,700	475.00	1,100.00	---	---
Renton	150,000	---	---	35.00	49.00
Auburn	90,000	14.00	20.00	7.00	10.00
Kent	60,000	---	---	14.00	20.00
Enumclaw, Redmond, Issaquah, Black Diamond, Pacific, and other rural community systems	66,000	---	---	14.00	19.00
Subtotal	3,785,700	489.00	1,120.00	70.00	98.00
RURAL-INDIVIDUAL USE	30,600	---	---	3.30[a]	4.50
INDUSTRIAL USE					
Municipally supplied:					
Seattle:					
Food and kindred	---	21.00	31.50[b]	---	---
Chemicals, metals, oils	---	87.20	96.00[c]	---	---
Lumber and wood	---	0.80	0.80	---	---
Stone, clay, glass	---	0.20	0.20	---	---
Transportation	---	110.00	145.00[c]	---	---
Renton:					
Food and kindred	---	0.06	0.09[b]	0.06	0.09[b]
Transportation	---	---	---	28.00	31.00[c]
Kent:					
Food and kindred	---	---	---	0.72	1.10[b]
Chemicals, metals, oils	---	---	---	2.40	2.60[c]
Auburn:					
Food and kindred	---	0.11	0.16	0.06	0.09[b]
Transportation	---	2.50	2.80	1.20	1.30[c]
Self-supplied:					
Food and kindred	---	---	---	1.65	2.50[b]
Chemicals, metals, oils	---	293.00	322.00[c]	---	---
Lumber and wood	---	2.10	2.10	0.10	0.10
Stone, clay, glass	---	5.00	5.00	3.90	3.90
Subtotal	---	521.97	605.65	38.09	42.68
Total[d]	3,816,300	1,011.00	1,725.70	111.40	145.20

[a]Based on 110 gpcd and 100 percent of rural-individual population by ground water.

[b]150 percent of average.

[c]110 percent of average.

[d]Figures are rounded.

TABLE 7-10. Summary of projected water needs

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly	Total usage (mgd) Average daily	Total usage (mgd) Maximum monthly
Municipal	1965	1,025,220	93.9	132.8	13.8	21.2	107.7	154.0
	1980	1,461,200	225.8	345.3	32.1	45.6	257.9	390.9
	2000	2,351,900	305.4	623.8	48.6	67.7	354.0	691.5
	2020	3,785,700	489.0	1120.0	70.0	98.0	559.0	1,218.0
Industrial	1965	—	54.4	60.9	2.3	2.7	56.7	63.6
	1980	—	89.6	100.4	4.9	5.6	94.5	106.0
	2000	—	214.2	239.6	13.5	15.2	227.7	254.8
	2020	—	522.0	605.7	38.1	42.7	540.1	648.4
Rural-Individual	1965	15,000	0.1	0.1	0.8	1.0	0.9	1.1
	1980	17,800	–	–	1.2	1.8	0.9	1.1
	2000	23,800	–	–	2.1	3.0	2.1	3.0
	2020	30,600	–	–	3.3	4.5	3.3	4.5
Totals	1965	1,040,220	148.4	193.8	16.9	24.9	165.3	218.7
	1980	1,479,000	315.4	445.7	38.2	53.0	353.6	498.7
	2000	2,375,700	519.6	863.4	64.2	85.9	583.8	949.3
	2020	3,816,300	1011.0	1725.7	111.4	145.2	1122.4	1870.9

Note: Usage figures are rounded to one decimal place.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 1,460 mgd by the year 2020. This is an increase of approximately 1,290 mgd over the 1965 average use. Optimum or peak water requirements will be almost two and one-half times this average or nearly 3,150 mgd. Tables 2-12 or 2-13, the Area Plans, summarize the basins' annual average and optimum requirement in relation to the remainder of the Area. Table 7-11, M&I Water Supply Needs, reviews the needs of the major water systems and/or users in the basin.

Approximately 70 percent of the total basin water needs in 2020 are expected to be provided by the Seattle Water Department. This system is expected to serve 90 percent of the 3,816,000 basin population, including the present communities now using ground water systems. Those communities in the extreme southern part of the basin, using ground water, will, in the future, be served by the city of Tacoma. Figure 7-7 shows the Seattle Water Departments proposed diversion and control works demand in relation to the optimum supply criteria.

Because Seattle receives water from the Snohomish Basin (Tolt River), much of the southeast portion of the basin lies within the logical Seattle service area. It would be possible for Seattle to deliver water directly to many of these customers or wholesale water to local water districts in these areas.

Supply pipelines and supply reservoirs throughout the Seattle water service area will be constructed and maintained by the Seattle Water Department. Water purveyor connections to the supply pipelines will be permitted at any convenient location. However, additional distribution storage reservoirs and distribution pipelines will be needed in coming years. Their size, location, elevation and routing will be the responsibility of local water purveyors.

One of the important water supply factors is the efect of industrial water use. The major trend is encirclement or location of industry within or near the metropolitan complexes. A large segment of water-using industry is projected to locate at the dwindling number of sites along major water resources. This results in most cases in an adequate supply and transmission of untreated industrial water. If this water is to be used for municipal purposes after the industries have developed it, the high cost of the treatment that would be required would, in some cases, make it infeasible to use as a municipal source.

BASIN PLANS

The Selected Basin Plan, as indicated in Table 7-2, calls for the further development of existing facilities. This plan is: for Seattle to continue, to a maximum, the development of the existing Tolt and Cedar River watersheds, and to develop new sources on the Snoqualmie and Skykomish Rivers. The remaining communities are projected to remain on ground water sources through 2020.

Consideration should be given to several conditions which would make it impractical for these communities to remain on ground water sources. They are: inadequate quality or municipal and/or industrial demand in excess of the quantity available. In such cases it may be possible for Seattle or Tacoma to extend service areas to supply the needs of these communities. Notably, Renton, Kent, and the surrounding communities would be supplied by the Seattle Water Department with the vicinity in and around Auburn receiving water from the Water Division of the City of Tacoma. (See Alternative Basin Plan, Table 7-13).

The total cost for the Basin Selected and Alternative Plans are $162 and $169 million, respectively. Supply and transmission, treatment, pumping, and chemical costs plus basin revenue are shown in the Selected Plan, Table 7-12, and the Alternative Plan, Table 7-13. Storage and distribution costs will remain the same for both plans. These costs plus the overall development expenses of the Basin are shown in the Area Selected and Alternative Plans, Tables 2-12 and 2-13, respectively.

Surface and ground water supplies can be economically utilized by rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources.

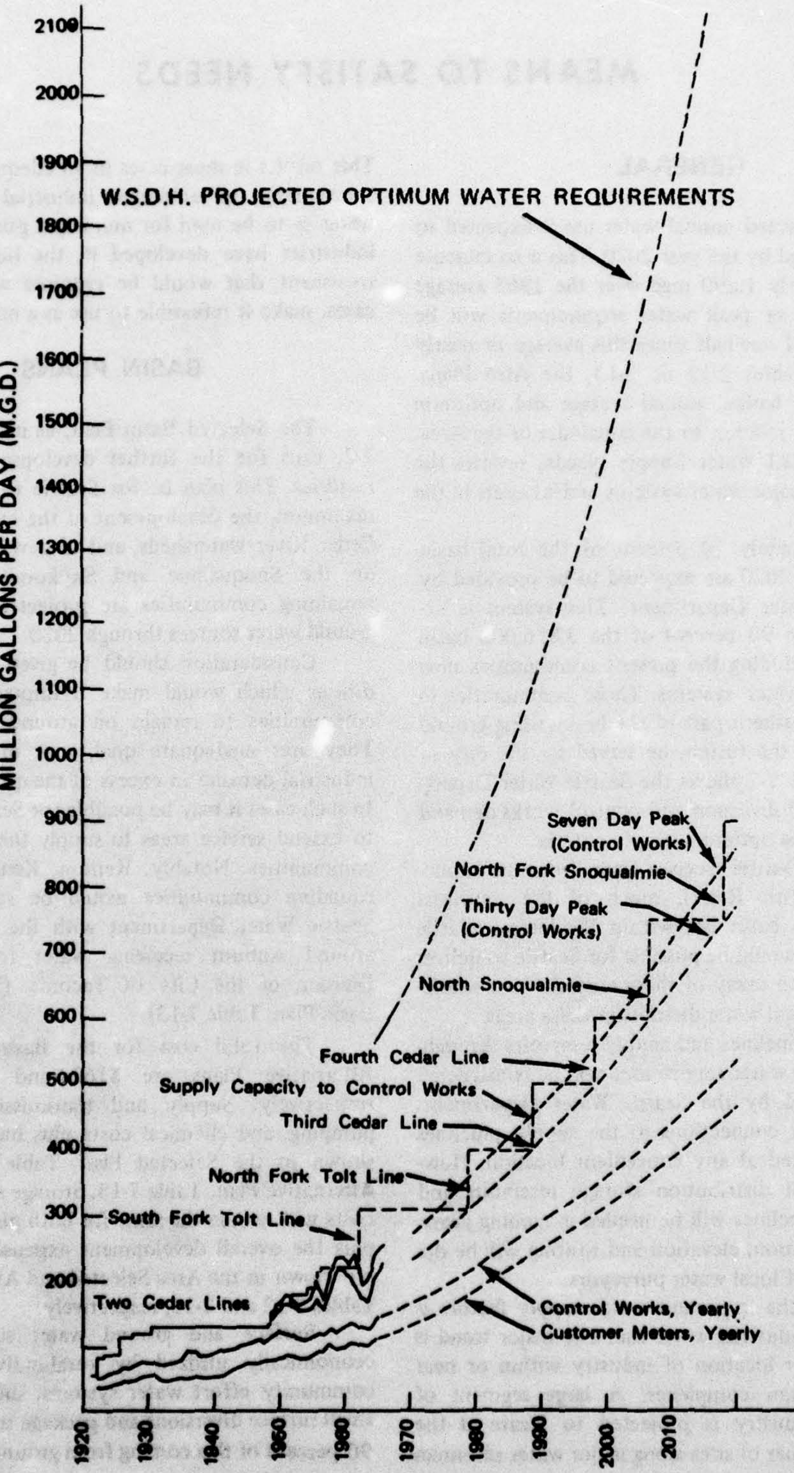


FIGURE 7-7. Means to satisfy future water supply demands for city of Seattle

TABLE 7-11. M & I Water Supply—Capital Improvements
Cedar-Green Basins

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	887,420	1,271,000	2,079,000	3,419,700
SEATTLE				
Optimum	606.8	876.5	1,473.1	2,522.9
Capital Improvements	265.8	270.7	596.6	1,049.8
Population Served	38,175	55,000	100,000	150,000
RENTON				
Optimum	26.3	39.3	75.7	129.9
Capital Improvements	20.0	13.0	36.4	54.2
Population Served	17,100	30,000	60,000	90,000
AUBURN				
Optimum	11.5	20.3	41.0	63.6
Capital Improvements	8.3	8.8	20.7	22.6
Population Served	10,457	20,000	40,000	60,000
KENT				
Optimum	7.4	14.0	28.1	43.3
Capital Improvements	4.4	6.6	14.1	15.2
Population Served	72,068	85,000	72,000	66,000
SMALL & RURAL COMMUNTIY SYSTEMS				
Optimum	47.5	56.0	47.5	43.5
Capital Improvements	31.8	8.5	0	0
Population Served	—	—	—	—
SELF SUPPLIED INDUSTRY				
Optimum	39.9	60.7	138.7	335.6
Capital Improvements	4.2	20.8	78.0	196.9
Population Served	1 025,220	1,461,000	2,351,000	3,785,700
TOTAL				
Capital Improvements	70	328	746	1339

NOTE: Figures are rounded.

The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Table 7-11, Summary of Projected Water Needs, shows level of need to 2020 from all sources.

FINANCE

Annual income as taken from Table 2-12 and 2-13 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amortized for 30 year at 5% for the Selected and Alternative Plans.

Year	Bond Service Available (x 1,000)	Annual Amortized Cost (x 1,000) Selected Plan	Alternative Plan
1965	$ 2,900	$ 1,653	$ 1,810
1980	5,100	5,610	6,040
2000	8,400	12,300	11,700
2020	15,500	20,800	20,800

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that by 1980 or sooner the Cedar-Green Basin will be unable to bond for the required water supply development, and future construction would involve extraordinary and excessive financial burden in relation to the basin's economic resources.

It appears to the Municipal and Industrial Water Supply Technical Committee that the Seattle Water Department, currently relying entirely on surface water, may have to develop ground water sources in the Cedar-Green Basin to meet peak summer demands and also for standby service. Ground water as Table 7-5 shows then could be used to meet future annual M&I Water needs. The feasibility of using ground water is the subject of future engineering studies but an apparent 12-25% of the basins future needs can be met from ground water.

TABLE 7-12. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Cedar-Green Basins

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Optimum Capacity MGD: Supply	Optimum Capacity MGD: Transm.	1967 Thousand Dollars — Amortized Capital Cost[b]: Supply & Transm.	Amortized Capital Cost[b]: Treatment	Amortized Capital Cost[b]: Iron Removal	Maintenance and Oper.: Pumping Power	Maintenance and Oper.: Chem.	Total Annual Income
SEATTLE												
Present	SW	Cedar River—Storage Dam and Reservoir (35,000 ac. ft.), Diversion and 2 Transmission Lines	Exist.	111	220	220				1,195	46	6,868
		South Fork, Tolt River Storage Dam and Reservoir (57,900 ac. ft.), and Transmission Lines	Exist.		90	90						
1985	SW	Present Needs Total—605mgd. (60mgd Supplied to Snohomish Basin, Small Community Systems served by Seattle Water Department not in this amount) ADD: Net supply and transmission capacity to existing 295mgd, Same Sources (Cedar River and South Fork, Tolt Rivers.)	1978		295	295	3,800					
1990	SW	[a] Future Needs Total—880mgd, ADD: Net Supply and Transmission capacity—275mgd from North Fork, Tolt River Storage Dam and Reservoir (17,000 ac. ft.) and Transmission Line	1978	257	275	275	16,800			2,910	111	16,009
2000	SW	Future Need Total—1,475mgd, ADD: Net Supply and Transmission Capacity—595mgd from Cedar River—Morse Lake Storage Dam and Reservoir, Diversion Dam and third Cedar River Transmission Line	1988	387	595	595	13,000			5,831	211	22,601
2020	SW	Future Needs Total—2,530mgd, ADD: Net Supply and Transmission Capacity—1,080mgd. Fourth Cedar River Transmission Line.[a]	1988	885	160	160	8,000			10,879	411	40,888
		[a]North Fork, Snoqualmie River Storage Dam and Reservoir, Transmission Line and Regulating Basin and from Regulating Basin to Treatment Plant.	[a]2007		380	380	25,600	5,600				
		[a]Future Needs Total—2,530mgd. ADD: Net Storage Reservoir—Supply and Transmission and Treatment. 550mgd from North Fork, Snoqualmie River or North Fork, Skykomish River.	2013		550	550	28,000	5,600				
					2,830	2,830	94,800	11,200				
SEATTLE SELECTED PLAN TOTAL							$106,100					
RENTON												
Present	GW	Local Ground Water Development	Exist.	5	6.3	6.3				32		380
1985	GW	20mgd Local Ground Water	1970		20	20	1,200					
1990	GW	Develop 13mgd Local Ground Water	1975	13	13	13	900			130		1,088
2000	GW	Develop 36mgd Local Ground Water	1985	30	36	36	2,100			316		2,464
2020	GW	Develop 56mgd Local Ground Water	2010	63	56	56	3,300			663		4,889
RENTON SELECTED PLAN TOTAL					131	131	$7,500					
KENT												
Present	GW	Local Ground Water Development	Exist.	3	3	3				11		117
1985	GW	5mgd Local Ground Water	1970		5	5	300					
1990	GW	Develop 7mgd Local Ground Water	1975	4	7	7	420			46		467
2000	GW	Develop 14mgd Local Ground Water	1985	10	14	14	840			103		1,168
2020	GW	Develop 16mgd Local Ground Water	2015	17	16	16	900			180		1,388

TABLE 7-12—Continued

Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	OPTIMUM CAPACITY M G D Supply	Transm.	1967 THOUSAND DOLLARS AMORTIZED CAPITAL COST[b] Supply & Transm.	Treat-ment	Iron Removal	MAINTENANCE AND OPER. Pumping Power	Chem.	Total Annual Income
KENT SELECTED PLAN TOTAL					44	44	$2,460					
AUBURN												
Present	GW	Local Ground Water Development	Exist.	3	3.2	3.2				34		350
1985	GW	9mgd Local Ground Water Development	1970		8	8	480					
1980	GW	Develop 9mgd Local Ground Water	1975	6	9	9	540			65		701
2000	GW	Develop 21mgd Local Ground Water	1995	14	21	21	840			146		1,150
2020	GW	Develop 23mgd Local Ground Water	2015	25	23	23	1,560			289		2,136
AUBURN SELECTED PLAN TOTAL					64	64	$ 3,420					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water Development	Exist.	6	15.7	15.7				165		1,869
1985	GW	32mgd Local Ground Water	1975		32	32	1,920					
1980	GW	9.0mgd Local Ground Water	1980	16	9	9	540			168		1,869
2000	GW	No Additional Requirements		15						158		1,752
2020	GW	No Additional Requirements		14						147		1,636
SMALL & RURAL COMMUNITY SYSTEMS SELECTED PLAN TOTAL					57	57	$ 2,460					
SELF SUPPLIED INDUSTRY												
Present	SW–GW	Local Development	Exist.	36	40	40	5,187			377		4,205
1980	SW–GW	Local Development	1970	56	21	21	2,704			584		4,599
2000	SW–GW	Local Development	1990	126	78	78	10,140			1,326		10,348
2020	SW–GW	Local Development	2010	306	197	197	22,087			3,211		22,338
SELF SUPPLIED INDUSTRY SELECTED PLAN TOTAL					336	336	$ 40,118					
SELECTED BASIN PLAN TOTAL							$162,068					

[a] Initial development.

[b] Does not inlcude storage and distribution costs; See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 7-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Cedar-Green Basins

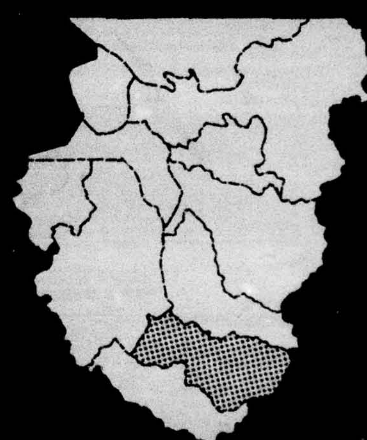
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Optimum Capacity MGD: Supply	Optimum Capacity MGD: Transm.	1967 Thousand Dollars, Amortized Capital Cost[b]: Supply & Transm.	Amortized Capital Cost[b]: Treat-ment	Amortized Capital Cost[b]: Iron Removal	Maintenance and Oper.: Pumping Power	Maintenance and Oper.: Chem.	Total Annual Income
RENTON												
Present	GW	Local Ground Water Development	Exist.	5	6	6				32	1	360
1980	SW	[a]26.3mgd—Seattle Water Department	1975		26	26	3,400					
1980	SW	15mgd—Seattle Water Department	1980	13	13	15	900			130	5	759
2000	SW	35mgd—Seattle Water Department	1980	30	36	35	2,100			315	12	1,752
2020	SW	55mgd—Seattle Water Department	2010	63	55	55	3,300			663	25	3,679
RENTON ALTERNATIVE PLAN TOTAL					131	131	$ 10,700					
KENT												
Present	GW	Local Ground Water Development	Exist.	3	3	3				11		117
1980	[a] SW	8.0mgd Seattle Water Department	1975		8	8	1,000					
1980	SW	Develop 7mgd Seattle Water Department	1980	4	7	7	420			46		234
2000	SW	Develop 14mgd Seattle Water Department	1991	10	14	14	840			103		584
2020	SW	Develop 15mgd Seattle Water Department	2010	17	15	15	900			180		993
KENT ALTERNATIVE PLAN TOTAL					47	47	$3,160					
AUBURN												
Present	GW	Local Ground Water Development	Exist.	3	3	3				34	1	380
1980	SW	[a]8mgd—Water Div—City of Tacoma	1975		8	8	1,400					
1980	SW	Develop 9mgd—Water Div—City of Tacoma	1980	6	9	9	540			65	2	360
2000	SW	Develop 21mgd—Water Div—City of Tacoma	1995	14	21	21	840			146	6	818
2020	SW	Develop 23mgd—Water Div-City of Tacoma	2015	28	23	23	1,560			289	11	1,635
AUBURN ALTERNATIVE PLAN TOTAL					64	64	$4,340					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water Development	Exist.	15	15	15				165	6	1,752
1980	SW	[a]32mgd—Seattle Water Department	1975		32	32	4,150				6	
1980	SW	[a]9.0mgd—Water Div-City of Tacoma	1980	16	9	9	540			168		934
2000		No Additional Requirements		15						158	6	876
2020		No Additional Requirements		4						147	6	234
SMALL & RURAL COMMUNITY SYSTEMS ALTERNATIVE PLAN TOTAL					41	41	$4,690					
SELF SUPPLIED INDUSTRY												
Present	SW–GW	Local Development	Exist.	36	39	39	5,187			377		4,205
1980	[a]SW–GW	21mgd—Seattle Water Department	1980	56	21	21	2,704			584		3,270
2000	SW–GW	78mgd—Seattle Water Department	1980	126	78	78	10,140			1,326		7,368
2020	SW–GW	100mgd—Seattle Water Department [a]98mgd—Water Div-City of Tacoma	2010 2000	306	198	198	22,087			3,211		17,870
SELF SUPPLIED INDUSTRY ALTERNATIVE PLAN TOTAL					336	336	$ 40,118					
SEATTLE												
		(No Feasible Alternative)					$108,100					
BASIN ALTERNATIVE PLAN TOTAL							$169,108					

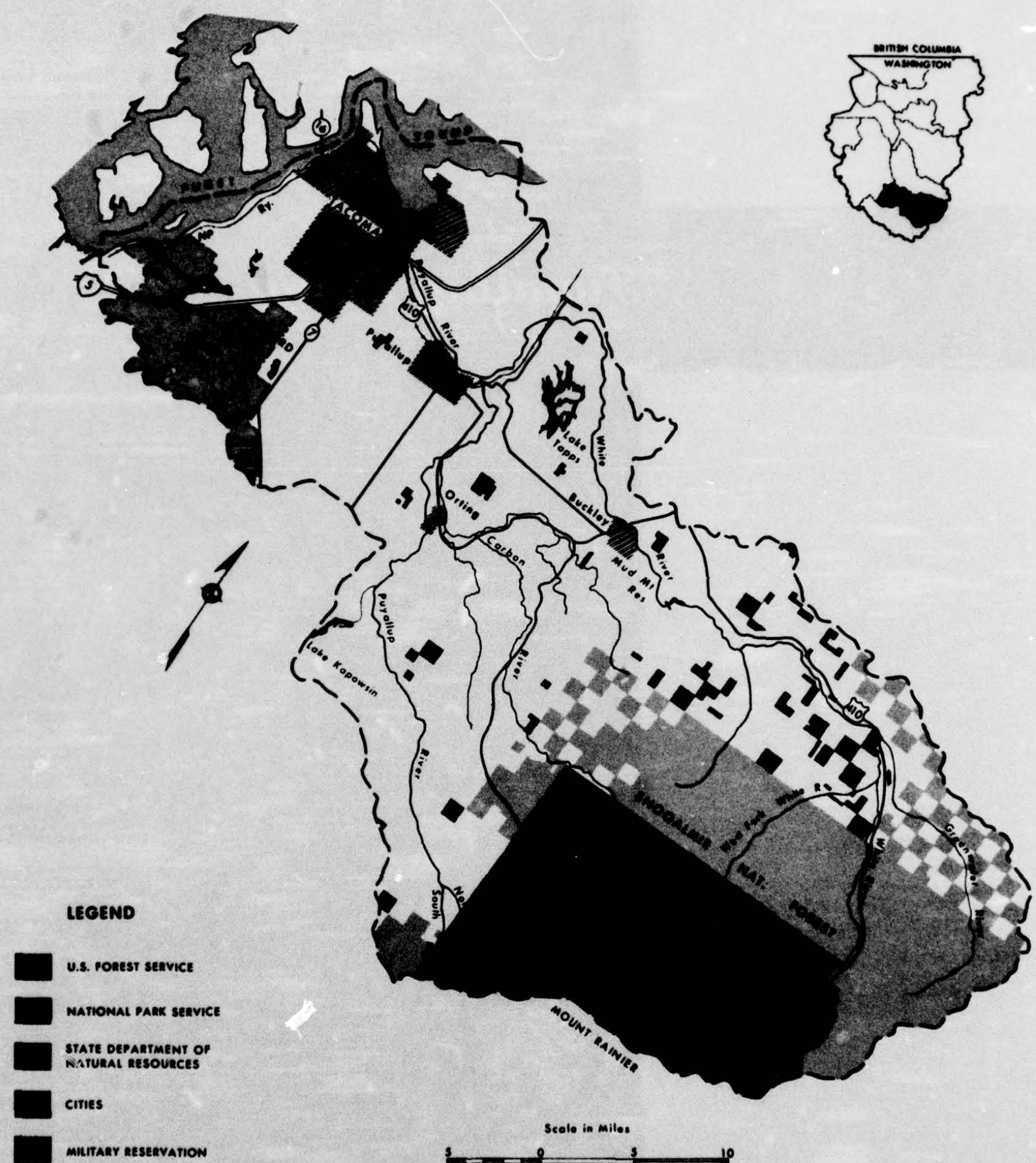
[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

Puyallup Basin





PUYALLUP BASIN

Figure 8—1 Land Ownership

PUYALLUP BASIN

INTRODUCTION

The Puyallup Basin, Figure 8-1, bounded on the east by Mount Rainier and on the west by Puget Sound, is located between the Cedar-Green and Nisqually-Deschutes Basins in the southwestern portion of the Puget Sound Area. Occupying about 1,254 square miles in Pierce and southern King counties, the basin encompasses the expanding urban-industrial center of Tacoma and the agriculture areas of Puyallup, Sumner, and surrounding communities.

The population and industry of the basin are projected to increase rapidly in the future, and the demand for municipal and industrial water supplies is expected to increase commensurate with this growth. Projections indicate that by the year 2020, water requirements may reach 550 million gallons per day. Present requirements are 100 million gallons per day. Although presently developed sources are capable of supplying present and immediate future demands, they will be unable to supply future demands of the magnitude indicated unless supplemented by additional facilities.

GEOGRAPHY

Rugged foothills, valleys, and streams, all radiating from Mount Rainier, occupy the greater part of the area and provide sharp contrasts in landscape to set the Puyallup Basin apart from any other basin in the Puget Sound Area. The eastern portion of the basin, a rugged, heavily forested, mountainous portion of the Cascade Range, is the source and watershed area for the Puyallup River and its tributaries. Mowich Lake and numerous smaller alpine lakes lie in the high mountain cirques. A series of low foothills and upland plateaus, separated by ridges and the deep canyon through which the rivers carve their way to Puget Sound, typify the central portion of the Basin. Lowland plateaus and rolling foothills, dotted with lakes and separated by the broad, fertile river valleys, extend from the midland area to the shores of Puget Sound.

The Puyallup River and its tributary rivers, the White, Carbon, and Mowich, drain more than 972 square miles and comprise the largest and most important drainage system in the basin.

From its source glacier on the southwestern slope of Mount Rainier, the Puyallup River flows some 46 miles as it drops 6,000 feet to empty into Commencement Bay at Tacoma. The White River (termed "Stuck River" below Auburn), principal tributary of the Puyallup, originates from Emmons Glacier and drains a 494 square mile area along the eastern and northern perimeters of the basin before joining the Puyallup River at Sumner. The mountainous area between the White and Puyallup rivers is drained by the Carbon River, Mowich River, and several smaller streams.

Numerous small creeks drain the lower western slopes and some of the lowland lakes. Chambers Creek and its tributaries, largest of the small stream systems, drains about 104 square miles of this area and carries the outflow from Steilacoom Lake to Puget Sound.

CLIMATE

The Puyallup Basin experiences a typical maritime climate of mild, wet winters and relatively cool, dry summers. Total annual precipitation in the basin, about 75 percent of which falls during October through March, ranges from 37 inches near Tacoma to 140 inches on Mount Rainier. The average lowland temperatures vary from about 3.3°C (38°F) in midwinter to about 18.3°C (65°F) in midsummer. Mild sea breezes from Puget Sound temper the hot periods so that air temperature exceeds 32°C (90°F) only 3 to 5 days a year.

POPULATION

A 1965 estimate indicated that about 345,200 people live within the Basin. About half of these 158,000 live in Tacoma, third largest city in the state. Most of the remaining population is scattered in and about numerous small communities in the Puyallup and White River valleys and adjacent to Puget Sound. The rugged eastern sector remains void of concentrated settlement.

ECONOMY

An industrial complex along the 14-mile shoreline of Commencement Bay employs more than 18,000 persons in a wide array of manufacturing concerns, and provides a major contribution to basin economy. More than 500 industries are located in this area, including lumber, pulp, and paper mills; furniture manufacturing plants; plywood factories; and food processing plants. Here also is the largest copper smelter on the Pacific Coast, a new electrochemical and metallurgical industrial center, and a diversified shipbuilding industry. The backbone of basin economy, however, continues to be the forest products industry. Harvesting of timber in Pierce County has increased over 100 percent since 1954.

Food and kindred products represent the second largest category of manufacturing and also account for a significant portion of basin income. The ever-expanding Boeing Company, both in Seattle and in Southern King County, has created a climate of economic growth. This growing economy has brought many smaller industries to locate in the northern portion of the basin. The continuing expansion of Boeing will increasingly have a favorable economic effect on the northern and central portions of the basin.

A mild climate and fertile soil make the 15-mile Puyallup valley the richest farming area of the Basin. Truck gardening, berry production, and a million-dollar flower industry, provide a significant and growing income to the Basin economy. The value of agricultural activities in Pierce County alone has risen from 20.6 million dollars in 1959 to 24.1 million dollars in 1964.

Although the economy presently depends primarily on trade and manufacturing, employment history shows that the basin is now becoming more dependent on nonmanufacturing activities, with governmental employment showing the greatest upward trend since 1948. Manufacturing employment has tended to remain static with very little fluctuation over the past 20 years. The average monthly employment for Pierce County in 1965 showed:

Agriculture	2,000
Mining	157
Construction	4,524
Manufacturing	18,194
Transportation (commercial and utilities)	3,658
Trade (wholesale and retail)	19,040
Finance, insurance, and real estate	4,288
Service	7,797
Government	9,078
Not classified	591

LAND USE

Land use in the basin varies from intense residential and industrial centers in Tacoma, through agricultural land in the Puyallup and Stuck River valleys, to woodland in the eastern foothills, where most of the area is presently covered by second-growth timber. Woodland predominates, accounting for 84 percent of the total acreage. Most of this acreage lies in federally owned or administered Mount Rainier National Park or Snoqualmie National Forest, respectively. Table 8-1 summarizes land use in the basin.

TABLE 8-1. General land use.

Use	Acres
Forestland	593,000
Urban buildup	97,000
Cropland	37,000
Inland water	11,000
Other land	26,000
Rangeland	6,000
Total land and inland water	770,000

PRESENT STATUS

WATER USE

Nearly 100 million gallons of fresh water, about two-thirds of which is provided by surface sources, is supplied each day to Puyallup Basin consumers. Municipal and industrial suppliers, drawing from both surface and ground sources, supply approximately 344,455 persons and numerous industries with about 100 mgd. Figure 8-2 shows municipal and industrial water use in Tacoma, largest water user in the basin. The remaining 4 mgd is supplied to rural and

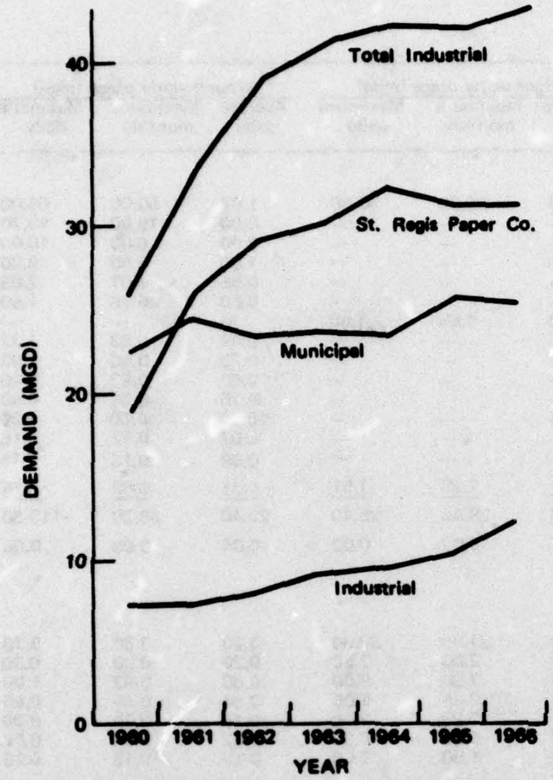


FIGURE 8-2. City of Tacoma municipal and industrial water use.

individual consumers from individual wells or small community distribution systems. In addition, salt water drawn from Puget Sound is used by some industries for purposes not affected by salinity. Fresh water consumption statistics for the Puyallup Basin are provided in Table 8-2; salt water consumption statistics are not presently available.

Municipal

Water used primarily for municipal purposes currently exceeds 40 mgd in the basin, and accounts for approximately 40 percent of the total basin water consumption. The 344,000 people living in metropolitan areas, cities, and towns exert an average per capita demand of 128 gpd.

The city of Tacoma uses about 50 percent of the Basin municipal water supply, or 22.4 mgd. In 1965 its 158,000 residents used an average of 142 gpcd.

The Lakewood Water District south of Tacoma, second largest municipal user in the basin, uses 3 million gallons daily, or 75 gpcd.

PHOTO 8-1. Tacoma Water Department supplies nearly three-fourths of all municipal water used in the basin.

Puyallup, Sumner, Buckley, and Orting together use more than 3 million gallons daily, or 120 gpcd. The city of Puyallup is the largest user of the group, and averages 1.8 mgd.

Industrial

Water used for industrial purposes averages more than 56 mgd, about 58 percent of the total water consumed in the Basin.

Surface waters supply more than .85 percent of the water used by industry. The St. Regis Paper Company alone used an average of 30.5 mgd in 1965, almost 54 percent of the daily water used by all industry in the basin.

The remaining industrial water users consist mainly of vegetable and fruit processing plants located in Puyallup and Sumner.

Tacoma's monthly demand profile is shown in Figure 8-3. During the summer months, municipal consumption runs 130 to 165 percent of the annual average water use. Industrial water use reaches a peak in August, 120 percent of the annual average. The total system profile shows the use to be greatest in late summer and fall. The leveling trend of the total demand profile is the result of large relatively constant industrial water use.

Rural-Individual

Approximately 745 rural-individual and small community consumers use approximately 0.05 mgd, about .05 percent of the total water used in the basin.

WATER SUPPLIES

Water is supplied to Puyallup basin consumers from the Green River, located in the adjacent basin to

TABLE 8-2. Water use (1965).

System	Estimated population served	Surface water usage (mgd)			Ground water usage (mgd)		
		Average daily	Maximum monthly	Maximum daily	Average daily	Maximum monthly	Maximum daily
MUNICIPAL USE							
Tacoma	158,000	20.40	26.80	32.80	1.97	60.00	65.00
Fort Lewis	60,000	—	—	—	8.00	15.00	19.70
Lakewood Water District	40,000	—	—	—	3.00	6.00	10.00
Puyallup	15,000	—	—	—	1.80	5.50	9.30
Parkland Light and Water Co.	12,000	—	—	—	0.95	1.07	2.05
Southeast Tacoma Mutual Water Co.	7,500	—	—	—	0.50	0.75	1.50
Buckley	6,000	0.60	0.80	1.00	—	—	—
Milton	4,600	—	—	—	0.44	0.83	1.32
Fircrest	4,350	—	—	—	0.25	0.50	1.00
Sumner	4,000	—	—	—	0.65	0.82	1.00
Bonney Lake	1,800	—	—	—	0.16	0.35	0.40
Steilacoom	1,670	—	—	—	0.20	0.60	1.00
Orting	1,500	—	—	—	0.07	0.12	0.15
Wilkeson W. D.	960	—	—	—	0.09	0.13	0.15
Other rural community systems	27,585	0.67	1.29	1.61	4.31	6.62	8.75
Subtotal	344,455	21.70	28.90	35.40	22.40	98.30	113.30
RURAL-INDIVIDUAL USE	745	0.01	0.02	0.02	0.04	0.06	0.08
INDUSTRIAL USE							
Municipally supplied:							
Tacoma:							
Paper and allied		28.60	31.90	33.30	3.20	3.50	3.70
Food and kindred		1.60	2.00	2.50	0.20	0.30	0.30
Chemicals		5.10	7.38	9.00	0.60	0.82	1.00
Primary metals		3.16	3.45	5.05	0.34	0.45	0.55
Lumber and wood		1.54	2.23	2.70	0.17	0.25	0.30
Stone, clay, glass		0.17	0.36	0.33	0.02	0.04	0.07
Other		0.92	1.50	2.00	0.10	0.15	0.25
Puyallup:							
Food and kindred		—	—	—	0.01	0.02	0.03
Stone, clay, glass		—	—	—	0.12	0.16	0.20
Sumner:							
Paper and allied		—	—	—	0.14	0.60	1.04
Stone, clay, glass		—	—	—	0.08	0.08	0.08
Self-supplied:							
Paper and allied (Chambers Cr.)		0.30	0.40	0.50	5.20	5.30	5.50
Paper and allied (Sumner)		—	—	—	0.92	1.00	1.10
Primary metals (Kaiser Al.)		—	—	—	2.90	3.00	3.10
Stone, clay, glass		0.09	0.11	0.13	0.30	0.40	0.53
Food and kindred (Sumner)		—	—	—	0.33	0.34	0.34
Subtotal		41.48	49.33	55.81	14.63	16.41	18.09
Total	345,200	63.16	78.24	91.24	37.06	114.81	139.49

b Estimated population served is not the population of the incorporated area of the city but is that population (sum of permanent and seasonal) from Table 2-7 which determines the "average rating" for each basin. This population has been included in the nearest municipal system since the municipality is often the water supplier for the smaller adjoining water distribution system.

the north; from the Puyallup River and its tributaries; from numerous creeks and small streams; and, to a lesser degree, from wells and springs. Puget Sound is also a source of supply for industries able to use salt water.

Surface sources supply about 70 percent of the water for municipal, industrial, and domestic uses in the basin. Nearly 69 percent of this is supplied by a trans-basin diversion from the Green River; the remaining 1 percent is drawn from basin streams. Ground water, taken mostly from wells in the Tacoma area, supplies about 30 percent of the water used in the basin. Basin water consumption figures are provided in table 8-2.

Municipal

The Green River supplies about 90 percent of the water to the Tacoma area. Water is diverted at

Palmer and flows through a 26-mile gravity line to the McMillan Reservoir south of Puyallup from where it is diverted to Tacoma as needed. Tacoma maintains close control over the Green River watershed to ensure a continued supply of quality water. Although Tacoma owns less than 10 percent of the watershed area, they do own the river frontage in the watershed approximately 26 miles upstream from the diversion facilities and have additionally negotiated agreements with other major landowners to insure controlled entry into the area.

In addition to the Green River source, Tacoma owns a system of 14 wells capable of providing 65.6 mgd that acts as an auxiliary supply. The wells are used during peak use periods and during times when the Green River supply is unuseable because of high turbidity. About 10 percent of the city's annual water consumption is obtained from these wells.

The Lakewood Water District south of Tacoma, second largest municipal supplier in the basin, provides approximately 40,000 persons with an average 3 mgd from a system of 22 wells. The remaining cities, towns, and water districts in the Basin, with the exception of Buckley which obtains its water supply from South Prairie Creek, rely primarily on springs and small wells to serve a combined population of about 55,000.

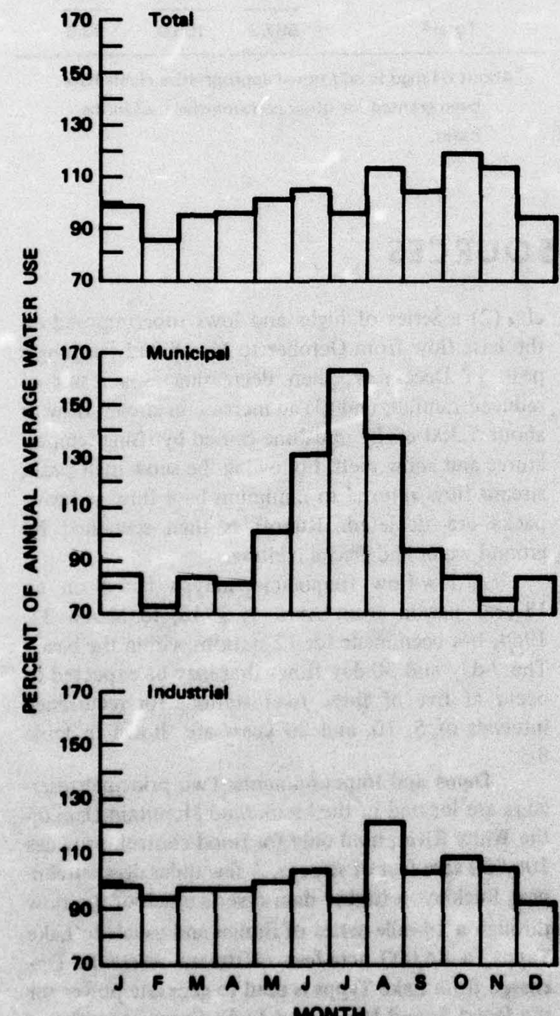


FIGURE 8-3. Tacoma water demand profiles.

Industrial

About 75 percent of all water supplied to industrial users in the Puyallup Basin is provided from Green River through the Tacoma municipal water system. About 50 industrial plants in the Tacoma area are supplied by some 75 privately owned wells. In addition, some industries draw water from the Puyallup River and other smaller streams to supplement that obtained from wells or municipal supplies. Salt water from Puget Sound is also used by several industries for cooling and other gross purposes.

Rural-Individual

An estimated 745 persons are supplied about 0.05 million gallons daily by rural-individual systems, more than 80 percent of which draw from ground water sources.

WATER RIGHTS

The Puyallup River Basin has a total of 962 recorded water-rights; of these 589 are surface and 373 are ground (1966-1967). Recorded prime rights appropriations allow a total rate of diversion of 621 mgd in the basin.

Power generation with recorded rights of 9 mgd and claims made to vested-rights by the Puget Sound Power & Light Company for 1,550 mgd is the largest surface water use in the basin. Municipal supply is also a major use with 468 mgd being allocated for this purpose. Single and community domestic uses have rights to divert 54 mgd. Significant quantities totaling 121 mgd may also be diverted as follows: fish propagation, 45 mgd; irrigation, 36 mgd; commercial and industrial, 19 mgd; recreation and beautification, 13 mgd; and mining, 8 mgd. Reservoir storage rights allow a retention of 51,671 acre-feet in this area.

Pending applications indicate an additional 17 mgd were under consideration for development in this area.

A total of 11 streams have been closed to further consumptive appropriation, and many diversions are subject to low-flow restrictions.

About 30 percent of the total ground water in the entire Puget Sound Area (287 mgd) is withdrawn in the Puyallup Basin. In addition to the above quantities, 37 mgd have been granted under supplemental rights, mostly to municipal systems of Tacoma and Lakewood. Pending applications indicate potential additional withdrawals totaling 8 mgd.

Municipal supply accounts for 40 percent of the appropriated prime right quantity or 119 mgd. Of equal importance are withdrawals for individual and community domestic supplies with issued rights totaling 102 mgd. Commercial, industrial and irrigation account for 67 mgd and 36 mgd, respectively.

The city of Tacoma has perfected rights of 26 wells with capacities exceeding 1.4 mgd, one of which produces as much as 13.7 mgd. Average production, however, per recorded wells in this area approximates 0.7 mgd. Table 8-3 shows water rights in the Puyallup Basin.

TABLE 8-3. Municipal & Industrial water rights.

Type	Municipal (mgd)	Individual and community domestic (mgd)	Industrial and commercial (mgd)
Surface water	468.6	54.4	25.8
Ground water	118.6	101.6	67.2
Total[a]	587.2	156.0	93.0

[a]About 64 mgd in additional appropriative rights have been granted for other consumptive uses in the basin.

WATER RESOURCES

SURFACE WATER

Quantity Available

Streams. Stream-flow contributions from 98 percent of the Puyallup River system have been measured at a gaging station on the river near Puyallup. During the period 1931-1960, the mean annual discharge at this station averaged 3,432 cfs. Records on the main stem of the Puyallup River near Orting, which include the Mowich River tributary, indicate that the mean annual discharge from the western foothills and slopes of Mount Rainier is about 631 cfs. Discharge records from the Carbon River, measured at the gaging station near Fairfax, show a mean annual discharge of 426 cfs. Runoff data from nearly half the White River basin were obtained at a gaging station on the White River near Buckley. During the 30-year reference period, the mean annual discharge averaged 1,490 cfs. Many small creeks drain directly into Puget Sound and Commencement Bay. The largest is Chambers Creek, with an annual average discharge of 120 cfs.

Stream flows are highest during early summer because of snow melt and are low during the late summer months. The Puyallup River system is characterized by: (1) a summer base flow of about 1,600 cfs; (2) a series of highs and lows superimposed on the base flow from October to March and reaching a peak in December, then decreasing as a result of reduced rainfall; and (3) an increase in stream flow to about 5,300 cfs by mid-June caused by rising temperatures and snow melt. Following the snow melt peak, stream flow returns to minimum base flow as snowpacks are depleted. Runoff is then sustained by ground water and glacial melting.

A low-flow frequency analysis based on an 18-year period from April 1, 1946, to March 31, 1964, has been made for 12 stations within the basin. The 7-day and 30-day flows that may be expected to occur at five of these river stations for recurrence intervals of 5, 10, and 20 years are shown in table 8-5.

Dams and Impoundments. Two principal reservoirs are located in the basin. Mud Mountain Dam on the White River, used only for flood control, provides 106,000 acre-feet of storage. A few miles downstream near Buckley, a timber dam diverts much of the flow through a 14-mile series of flumes and canals to Lake Tapps, a 44,000 acre-feet offstream reservoir. Discharge from Lake Tapps is used to generate power for the Puget Sound Power and Light Company plant at Dieringer.

Part of the Puyallup River flow is diverted through the Electron power plant, 23 miles southeast of Tacoma. The diversion dam, 14 miles upstream from the powerhouse, creates a small reservoir of 120 acre-feet.

Lakes. The total amount of storage in lakes and glaciers of the basin is not known, but surface areas can be used to provide at least a comparative indication of the amount of water that is stored. The total surface area of lakes is 10.5 square miles, of which 5.9 square miles consists of reservoirs. Glaciers in the basin are on Mount Rainier, and their surface area is about 24.7 square miles. Lakes in the basin do not presently contribute substantially as a principal or industrial water supply.

Quality

A number of the water quality characteristics of the Puyallup River and its significant tributaries and the Chambers Creek system, have been measured since October 1960 and are shown in Table 8-4.

The data in table 8-4 indicate that glacier fed streams are commonly turbid and colored but are otherwise excellent in quality. Those streams flowing directly into Puget Sound are generally affected by local land use and drainage resulting in increased coliform concentrations, but with no apparent adverse effect on their chemical quality. The following detailed discussion of water quality characteristics in the basin is based on data gathered from the monitoring stations listed in Table 8-5. Refer to

TABLE 8-4. Surface water quality (page 1 of 2).

		mg/l													mg/l								mg/l		mg/l		
Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (μmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2)	Iron (Fe)	Boron (B)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen	Oxygen saturation (%)	Total	Noncarbonate (mg/l)	Coliform (MPN)
SOUTH PRAIRIE CREEK AT SOUTH PRAIRIE																			FEBRUARY 1955 THROUGH SEPT 1955								
Maximum	902	70	11.0	2.9	5.8	0.7	51	---	7.7	2.2	0.3	1.9	106	---	---	14.0	0.00	0.06	7.3	---	---	---	---	---	30	1	---
Mean	---	57	7.8	2.0	4.1	0.6	36	---	6.1	1.7	0.2	1.1	78	---	---	12.5	0.00	0.03	---	---	---	---	---	---	28	1	---
Minimum	54	43	4.6	1.0	2.5	0.6	18	---	4.5	1.2	0.1	0.3	49	---	---	11.0	0.00	0.02	6.7	---	---	---	---	---	16	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
PUYALLUP RIVER AT ALDERTON																			FEBRUARY 1955 THROUGH AUGUST 1955								
Maximum	4,190	57	5.6	1.6	3.0	0.8	26	---	5.1	1.0	0.2	1.6	59	---	---	12.0	0.06	0.14	7.2	---	---	---	---	---	21	0	---
Mean	---	52	5.2	1.3	2.8	0.8	23	---	4.1	1.0	0.1	0.9	53	---	---	11.0	0.04	0.08	---	---	---	---	---	---	19	0	---
Minimum	1,020	46	4.8	1.0	2.6	0.7	20	---	3.0	1.0	0.1	0.3	47	---	---	10.0	0.03	0.01	6.8	---	---	---	---	---	16	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
WHITE RIVER AT GREENWATER																			FEBRUARY 1955 THROUGH AUGUST 1955								
Maximum	3,040	62	5.6	0.9	3.9	0.8	18	---	10.0	1.2	0.3	0.9	58	---	---	14.0	0.02	0.12	7.0	---	---	---	---	---	18	3	---
Mean	---	53	5.0	0.8	3.1	0.7	18	---	7.2	0.9	0.2	0.6	51	---	---	13.5	0.01	0.12	---	---	---	---	---	---	16	2	---
Minimum	723	44	4.4	0.8	2.3	0.6	17	---	4.4	0.5	0.1	0.3	43	---	---	13.0	0.00	0.11	6.9	---	---	---	---	---	14	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
GREENWATER RIVER AT GREENWATER																			FEBRUARY 1955 THROUGH AUGUST 1955								
Maximum	1,150	50	6.7	1.2	4.3	0.5	33	---	3.3	1.2	0.3	0.9	61	---	---	16.0	0.03	0.08	7.5	---	---	---	---	---	22	0	---
Mean	---	47	5.6	0.9	3.4	0.4	26	---	2.9	1.1	0.2	0.5	51	---	---	15.0	0.02	0.06	---	---	---	---	---	---	18	0	---
Minimum	73	43	4.6	0.5	2.5	0.3	19	---	2.6	1.0	0.0	0.1	41	---	---	14.0	0.00	0.02	6.5	---	---	---	---	---	14	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
WHITE RIVER NEAR BUCKLEY																			AUGUST 1947 THROUGH AUGUST 1955								
Maximum	3,390	56	7.2	1.2	3.7	0.8	26	---	14.0	1.5	0.3	1.1	61	---	---	17.0	0.07	0.12	7.2	---	---	---	---	---	22	1	---
Mean	---	52	5.3	0.9	2.8	0.8	21	---	8.4	1.0	0.2	0.5	49	---	---	13.4	0.06	0.06	---	---	---	---	---	---	17	0	---
Minimum	655	42	3.2	0.5	1.9	0.7	12	---	3.8	0.2	0.1	0.2	34	---	---	9.5	0.03	0.01	6.6	---	---	---	---	---	10	0	---
Number	4	4	4	4	2	2	4	---	4	4	3	4	4	---	---	4	3	3	3	---	---	---	---	---	4	4	---
BOISE CREEK ABOVE RESERVOIR NEAR ENUMCLAW																			JANUARY 1963 THROUGH OCTOBER 1964								
Maximum	29	40	4.6	0.8	3.0	0.8	22	0	2.4	2.0	0.1	1.1	40	0.03	0.08	14.0	0.08	0.02	7.2	15	5	11.0	12.4	98	14	0	160
Mean	---	34	3.6	0.6	2.5	0.5	17	0	1.0	1.3	0.0	0.7	34	0.02	0.04	13.0	0.06	0.01	---	---	---	6.7	11.2	94	12	0	37
Minimum	7	30	3.0	0.4	2.0	0.1	14	0	0.2	1.0	0.0	0.3	29	0.02	0.02	12.0	0.04	0.00	6.8	5	0	3.0	10.2	88	9	0	0
Number	7	8	8	8	8	8	8	8	8	8	8	8	8	8	4	8	4	4	8	8	8	8	8	8	8	8	8
BOISE CREEK AT BUCKLEY																			JANUARY 1963 THROUGH OCTOBER 1964								
Maximum	---	67	7.0	1.9	5.5	3.0	32	0	4.8	3.5	0.1	4.7	76	0.64	1.60	18.0	0.66	0.07	6.8	60	20	16.0	11.8	98	24	2	24,000
Mean	---	57	5.9	1.4	3.9	1.8	26	0	3.2	2.4	0.1	3.2	64	0.28	0.93	16.5	0.42	0.04	---	---	---	10.0	10.5	95	21	1	47,938
Minimum	---	49	5.0	1.1	3.0	1.2	22	0	2.4	1.0	0.0	2.0	51	0.11	0.22	15.0	0.29	0.03	6.4	10	5	4.8	9.0	93	18	0	1,500
Number	---	8	8	8	8	8	8	8	8	8	8	8	8	8	5	8	3	3	8	8	8	8	8	8	8	8	8
WHITE RIVER NEAR SUMNER																			OCTOBER 1961 THROUGH MARCH 1966								
Maximum	3,320	88	12.0	4.1	5.3	2.2	49	0	14.0	3.2	0.3	3.3	123	0.28	---	20.0	1.80	0.16	8.7	26	230	26.0	14.8	123	47	8	11,000
Mean	---	63	8.5	2.0	3.8	1.1	34	0	8.6	1.9	0.1	0.7	81	0.08	---	15.4	0.29	0.02	---	---	---	10.7	11.2	104	30	2	1,410
Minimum	57	37	4.4	0.7	2.3	0.3	16	0	4.2	0.5	0.0	0.0	46	0.02	---	10.0	0.02	0.00	6.6	0	0	3.4	8.4	79	15	0	0
Number	38	53	52	52	52	52	52	26	52	52	52	53	53	47	---	52	49	12	53	53	46	51	51	51	53	53	51
PUYALLUP RIVER AT PUYALLUP																			OCTOBER 1961 THROUGH APRIL 1966								
Maximum	8,830	74	11.0	3.1	5.4	1.8	46	0	12.0	3.0	0.3	2.0	112	0.13	---	18.0	1.60	0.04	7.6	20	100	18.3	12.4	112	40	4	24,000
Mean	---	53	6.8	1.7	3.6	0.9	28	0	6.8	1.6	0.1	0.7	67	0.06	---	13.8	0.44	0.01	---	---	---	9.3	10.8	97	24	1	6,521
Minimum	1,080	36	4.8	0.8	2.2	0.4	20	0	4.0	0.8	0.0	0.1	46	0.01	---	9.9	0.01	0.00	6.3	5	0	2.9	9.3	87	16	0	0
Number	26	42	42	42	42	42	42	28	42	42	42	42	42	28	---	42	30	13	42	42	16	42	43	42	42	42	43

TABLE 8-4. Surface water quality (page 2 of 2)

Item	Discharge (cfs)	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Specific conductance (µmho)	Orthophosphate (PO_4)	Total phosphate (PO_4)	Silica (SiO_2) (mg/l)	Iron (Fe)	Boron (B) (mg/l)	pH	Color (standard units)	Turbidity (JCU)	Temperature (°C)	Dissolved oxygen (mg/l)	Oxygen saturation (%)	Total (mg/l)	Noncarbonate (mg/l)	Coliform (MPN)
			mg/l												mg/l												
CLOVER CREEK NEAR PARKLAND — OCTOBER 1962 THROUGH SEPTEMBER 1964																											
Maximum	---	81	10.0	4.0	4.8	1.5	48	0	6.8	4.0	0.2	5.2	99	0.15	0.15	23.0	0.30	0.06	7.4	70	5	19.5	13.4	149	38	6	11,000
Mean	---	74	9.0	3.4	4.4	1.0	43	0	4.9	3.0	0.1	3.1	96	0.04	0.07	19.9	0.04	0.02	---	---	---	10.9	11.5	108	36	1	593
Minimum	---	68	7.5	2.4	3.8	0.5	28	0	3.2	2.5	0.0	2.1	84	0.02	0.03	15.0	0.00	0.00	6.6	0	0	6.1	9.3	81	28	0	0
Number	---	24	24	24	24	24	24	12	24	24	24	24	24	24	22	24	19	4	24	24	24	24	24	24	24	24	24
CLOVER CREEK ABOVE STEILACOOM LAKE NEAR TACOMA — OCTOBER 1962 THROUGH SEPT 1965																											
Maximum	---	83	11.0	4.0	5.3	1.5	48	0	8.4	4.5	0.2	7.2	109	0.29	0.35	21.0	0.38	0.02	7.7	30	20	21.0	13.1	142	42	6	24,000
Mean	---	67	9.1	3.1	4.6	0.9	40	0	5.9	3.7	0.1	3.2	96	0.06	0.12	12.7	0.12	0.01	---	---	---	11.2	11.1	105	36	3	1,521
Minimum	---	54	7.5	1.8	4.2	0.6	30	0	4.2	3.0	0.0	0.6	82	0.00	0.03	7.4	0.00	0.00	6.5	5	0	4.5	8.8	81	29	0	0
Number	---	35	35	35	35	35	35	24	35	35	35	35	36	35	34	35	29	6	35	35	35	35	35	35	35	35	35
CHAMBERS CREEK BELOW STEILACOOM LAKE NEAR STEILACOOM — OCT 1962 THROUGH SEPT 1964																											
Maximum	273	88	12.0	4.2	5.7	1.6	60	0	8.6	4.2	0.1	4.6	125	0.88	1.00	19.0	0.11	0.05	8.1	10	5	24.0	13.3	139	47	7	390
Mean	---	73	10.5	3.6	5.1	1.0	47	0	7.3	3.9	0.1	2.2	108	0.25	0.29	13.5	0.04	0.03	---	---	---	12.8	10.8	105	41	3	90
Minimum	27	53	9.5	2.7	4.6	0.7	38	0	5.4	2.8	0.0	0.1	96	0.04	0.05	1.2	0.00	0.00	6.6	0	0	6.1	8.0	76	35	0	0
Number	24	24	24	24	24	24	24	12	24	24	24	24	24	24	23	24	18	4	24	24	24	24	24	24	24	24	24
FLETT CREEK AT TACOMA — OCTOBER 1962 THROUGH SEPTEMBER 1965																											
Maximum	51	156	22.0	8.9	9.0	6.6	75	0	35.0	10.0	0.3	13.0	220	0.98	1.10	22.0	1.10	0.03	7.8	160	120	20.1	13.2	150	85	36	24,000
Mean	---	120	16.0	6.5	7.2	2.7	53	0	20.8	7.9	0.1	10.1	177	0.20	0.28	16.6	0.28	0.01	---	---	---	11.3	8.9	84	67	23	5,343
Minimum	2	98	12.0	4.2	5.1	1.6	30	0	17.0	4.5	0.0	6.8	131	0.07	0.09	12.0	0.02	0.00	6.3	5	0	7.3	4.5	41	47	15	91
Number	24	36	36	36	36	36	36	24	36	36	36	36	36	36	35	36	29	6	36	36	36	36	36	36	36	36	36
LEACH CREEK NEAR STEILACOOM — OCTOBER 1962 THROUGH SEPTEMBER 1965																											
Maximum	73	121	14.0	9.2	6.7	2.1	70	0	17.0	6.5	0.3	5.4	167	0.19	0.51	30.0	0.29	0.06	7.8	100	15	15.0	12.6	111	68	16	11,000
Mean	---	106	11.2	7.6	5.6	1.5	59	0	13.1	4.6	0.1	4.0	145	0.13	0.20	25.6	0.12	0.03	---	---	---	9.9	10.7	97	59	11	1,566
Minimum	6	83	8.0	4.4	4.0	1.1	26	0	11.0	2.8	0.0	1.3	101	0.02	0.11	16.0	0.03*	0.00	6.4	0	0	5.8	9.0	82	38	8	0
Number	24	36	36	36	36	36	36	24	36	36	36	36	36	36	35	36	32	6	36	36	36	36	36	36	36	36	36
CHAMBERS CREEK NEAR STEILACOOM — OCTOBER 1962 THROUGH APRIL 1966																											
Maximum	348	100	12.0	6.2	6.2	2.3	57	0	12.0	6.0	0.2	5.6	139	0.94	1.20	23.0	0.52	0.10	7.8	70	20	17.4	13.0	113	56	10	11,000
Mean	---	84	11.0	4.8	5.5	1.3	49	0	9.7	4.6	0.1	4.2	123	0.20	0.28	16.9	0.09	0.04	---	---	---	11.3	10.1	94	47	7	933
Minimum	37	73	8.0	3.3	4.0	0.9	30	0	6.9	3.0	0.0	2.7	97	0.04	0.10	11.0	0.00	0.00	6.7	0	0	6.6	8.3	82	35	2	0
Number	26	49	49	49	49	49	49	35	49	49	49	49	49	36	x35	49	32	10	49	49	36	51	50	50	49	49	51
KAPOWSIN CREEK NEAR KAPOWSIN — FEBRUARY 1955 AND SEPTEMBER 1955																											
Maximum	246	51	4.8	1.4	3.4	0.9	28	---	1.5	2.0	0.3	1.6	53	---	---	16.0	0.08	0.08	6.7	---	---	---	---	---	18	0	---
Mean	---	50	4.1	1.3	3.2	0.9	23	---	1.1	1.5	0.3	1.1	48	---	---	14.5	0.05	0.04	---	---	---	---	---	---	16	0	---
Minimum	6	49	3.4	1.1	3.0	0.9	18	---	0.7	1.0	0.2	0.7	43	---	---	13.0	0.03	0.01	6.6	---	---	---	---	---	13	0	---
Number	2	2	2	2	2	2	2	---	2	2	2	2	2	---	---	2	2	2	2	---	---	---	---	---	2	2	---
PUYALLUP RIVER NEAR ORTING — JULY 1959 THROUGH MARCH 1966																											
Maximum	3,240	65	7.5	2.3	4.0	1.1	30	0	16.0	2.8	0.3	1.6	74	0.14	---	18.0	9.50	0.11	7.6	40	500	15.0	13.4	108	26	12	430
Mean	---	46	5.2	1.3	2.7	0.6	21	0	5.7	1.1	0.1	0.3	52	0.03	---	13.4	0.68	0.02	---	---	---	8.0	11.4	99	18	2	115
Minimum	265	32	3.5	0.6	1.8	0.2	8	0	1.9	0.0	0.0	0.0	40	0.00	---	8.9	0.02	0.00	6.2	0	0	1.0	9.2	89	13	0	0
Number	24	32	32	32	32	32	32	17	32	32	32	32	32	26	---	31	28	11	32	32	9	29	30	29	32	32	30
CARBON RIVER NEAR FAIRFAX — FEBRUARY 1955 THROUGH AUGUST 1964																											
Maximum	1,760	52	6.5	1.7	4.0	1.0	34	0	3.6	1.5	0.2	1.6	64	0.10	---	12.0	0.90	0.08	7.4	10	370	11.5	12.4	103	23	0	430
Mean	---	39	4.5	1.0	2.9	0.7	23	0	2.3	0.9	0.1	0.5	44	0.03	---	9.6	0.20	0.03	---	---	---	8.0	11.6	101	15	0	143
Minimum	194	23	2.4	0.3	1.7	0.5	12	0	1.4	0.2	0.0	0.0	28	0.00	---	6.9	0.00	0.00	6.6	5	0	5.1	10.6	100	7	0	30
Number	9	9	9	9	9	9	9	7	9	9	9	9	9	7	---	9	9	5	9	9	7	7	7	7	9	9	7

Appendix XIII for a map showing the location of the stations.

Physical. Average dissolved oxygen concentrations in the Puyallup River and its tributaries are high, ranging from 10.8 mg/l to 11.6 mg/l. The lowest minimum dissolved oxygen recorded for this river system was 8.4 mg/l on the White River near Sumner. The only evidence of any oxygen deficit in the basin is in the Chambers Creek area, where the minimum dissolved oxygen content in Flett Creek dropped to a low of 4.5 mg/l.

The dissolved oxygen concentration in the Puyallup River system remains at nearly 100 percent saturation (9.7 mg/l at 20°C [68°F]) throughout the year except for slight variations caused by specific changes in climatic and geologic conditions. In the Chambers Creek area, the dissolved oxygen concentrations are also at saturation levels, except for Flett Creek, where the percentage of saturation is generally less than 100 percent because of the higher temperatures of its ground water sources and the adjacent land uses.

The temperature of the Puyallup River and its tributary, the Carbon, is relatively low, normally less than 18°C (64°F) during the warmest months, and reflects their glacial origins. The Puyallup warms up downstream, and has reached a recorded high of 18.3°C (65°F). The increase in temperature during

TABLE 8-5. Low-flow frequency.

Station	Recurrence interval (years)	7-day low flow (cfs)	30-day low flow (cfs)
Puyallup River at Puyallup	5	1,010	1,250
	10	910	1,150
	20	820	1,050
Puyallup River near Orting	5	210	285
	10	188	260
	20	170	240
Carbon River near Fairfax	5	110	133
	10	98	118
	20	89	105
White River near Buckley	5	390	500
	10	340	440
	20	300	400
Chambers Creek below Leach Creek near Steilacoom	5	34	38
	10	32	35
	20	31	33

the summer is probably caused by the contribution of warm water from the White River, which has attained a temperature of 26.0° C (79° F) near Sumner.

The warmest stream temperatures usually occur near Lake Steilacoom, where maximums of 24.0° C (75° F) on Chambers Creek and 21.0° C (70° F) on Clover Creek have been recorded. Flett Creek, at Tacoma, has reached a temperature of more than 21.1° C (70° F). Temperatures on Chambers Creek near its outlet at Steilacoom have reached a maximum of 17.4° C (63° F).

The glacier-fed Puyallup River and its tributaries are extremely turbid (Photo 8-2) during most of the year, with minimum turbidity occuring during the winter when glacial melt is at a minimum. Turbidities for the Puyallup River, White River, and Carbon River are less than 15 JTU, and 5 JTU, respectively. Maximum turbidity of these streams ranges from 230 to 500 JTU.

As indicated by the high turbidity levels of the Puyallup River system, stream-borne sediment in this system exceeds desirable limits throughout most of each year. Sediment concentrations of 10 to 60,000 mg/l in the White River have been recorded. The sediment concentration in lowland streams not fed by glaciers is usually within desirable limits.

PHOTO 8-2. The turbid water of the Puyallup River is limited to such uses as irrigation.

Chemical. (See table 8-4.) The surface water in the basin is, in general, soft, low in dissolved solids, and of excellent quality. The concentration of total dissolved solids in the Puyallup River system rarely exceeds 70 mg/l.

Bacteriological. (See table 8-4.) The bacteriological quality of streams in the basin is highly variable, with total coliform densities ranging from less than 430 MPN in the Puyallup River near Orting to an occasional maximum high of 240,000 MPN in Boise Creek near Buckley.

The MPN value of coliform bacteria in Chambers Creek below Lake Steilacoom is usually less than 100, but is occasionally as high as 390. Its overall quality compares favorably with natural waters found in the basin. However, downstream near the town of Steilacoom, MPN values in excess of 700, with a high of 11,000, have been recorded in this same stream. Leach Creek has MPN values usually in excess of 1,500. Flett Creek at Tacoma contains an even greater concentration--5,343 MPN--and is, therefore, the lowest quality stream in the basin. The entire length of Clover Creek is of similar, sanitary quality with maximums of 11,000 MPN near Parkland and 24,000 MPN farther downstream at Lake Steilacoom.

GROUND WATER

Quantity Available

Plentiful supplies of ground water exist in many of the lowland areas of the basin. Deposits of coarse sedimentary material, the important lowland aquifers,

are nearly continuous over about a 420 square-mile area.

Recessional outwash deposits, consisting mostly of coarse sand and gravel, are the most productive aquifers in the lowlands because their high transmissibility results in greater specific capacities and yields. Alluvium (silt, clay, and fine sand), which occurs mainly on the flood plains of the Puyallup and White River valleys, appears capable of yielding appreciable quantities of water to wells. Wells in glacial and older semiconsolidated sediments generally yield small amounts of water.

Sand and gravel aquifers probably occur in the mountains in sediments that cover about a 30-square mile area. Assuming such qualities as saturated thickness and permeability, these aquifers might be developed to supply ground water on a sustained basis. In other mountainous sections, ground water is obtainable only from consolidated and semiconsolidated rocks, which yield at best only 10 gallons per minute.

Precipitation and slope runoff supply the aquifers, which may receive an average of about 130,000 acre-feet of recharge annually. Most of the ground water discharges through springs and seeps around the margins of the river valleys, or directly into Puget Sound.

Quality

The ground water in the basin is of generally good quality, though objectionable concentrations of iron and sodium occur locally in water from the Puyallup and White River valleys. The water is low in dissolved solids, usually less than 200 mg/l, and hardness does not usually exceed 60 mg/l. Silica concentrations range from 7 to 54 mg/l, and average about 30 mg/l. Sodium concentrations are relatively high in the Puyallup River valley, and often exceed 50 mg/l as compared to an average of less than 10 mg/l in other parts of the basin.

Table 8-6 summarizes ground water quality data for selected wells in the basin.

TABLE 8-6. Ground water quality.

Owner	Location code[a]	Date	Temperature (°C)	Color (standard units)	Turbidity (JCU)	Silica (Sio$_2$) (mg/l)	Iron (Fe) (mg/l)	Calcium (Ca) (mg/l)	Magnesium (mg) (mg/l)	Sodium (Na) (mg/l)	Potassium (K) (mg/l)	Nitrate (NO$_3$) (mg/l)	Orthophosphate (PO$_4$) (mg/l)	Dissolved solids (mg/l)	Hardness (as CaCO$_3$) (mg/l)	Specific conductance (umho)[c]	pH
Ashford Headquarters (Park)	15/07E	12/13/67	10.0	4	2.00	15.00	0.12	19.20	0.80	1.13	2.76	2.04	0.20	—	54.0	120.0	8.25
Bonney Lake (spring)	20/05E/33	11/6/67	15.0	5	2.25	22.00	0.20	12.00	12.15	2.12	2.75	3.99	0.24	—	80.0	118.0	7.50
Fruitland Water (wells)	19/04E/4	5/24/67	15.0	11	1.50	11.25	0.17	8.81	9.60	2.96	2.69	1.42	0.31	67.0	44.0	112.0	7.50
City of Roy	18/02E	5/19/67	15.0	8	1.50	20.50	0.19	8.00	2.80	2.64	5.69	10.99	0.24	65.2	24.0	95.0	6.73
Parkland Light and Water																	
Well	19/03E/9	5/15/67	15.0	6	0.82	7.50	0.78	10.60	4.76	5.13	3.43	3.22	0.62	72.2	45.6	111.1	7.45
Well	19/03E/17	5/15/67	15.0	4	1.00	8.00	0.19	13.60	7.48	3.57	2.34	12.31	0.21	81.4	64.8	148.0	6.85
Well	--	5/15/67	15.0	20	2.20	7.50	0.39	28.00	0.49	24.29	3.98	5.48	0.41	13[illegible]	72.0	170.0	9.50
City of South Prairie																	
Well	19/06/18	3/27/67	10.6	10	0.22	23.75	0.23	11.21	10.69	5.39	2.11	3.92	0.80	100.8	72.0	144.0	7.78
Spring	--	5/7/67	6.7	7	1.20	7.00	0.12	14.42	6.32	2.09	1.74	1.95	0.24	75.6	62.0	134.0	7.49
Well	--	12/13/66	15.0	7	0.72	14.75	0.46	10.41	9.50	14.95	3.08	2.22	0.94	150.3	44.0	166.4	7.55
Milton Water System	--	11/24/66	—	—	—	—	0.32	—	—	—	—	19.49	—	—	—	—	7.03
Lakewood Water District																	
Well A2	19/02E/1	9/19/60	—	—	—	43.30	0.10	9.00	4.80	16.70	—	—	—	87.0	42.2	—	7.50
Well D2	19/02E/2	8/5/59	—	1	—	42.30	0.05	8.90	5.80	14.70	—	—	—	108.0	46.1	—	6.90
Well D3	19/02E/4	9/29/60	—	—	—	37.70	0.05	10.70	5.50	13.60	—	—	—	86.0	49.4	—	7.70
Well K2	19/02E/10	12/3/58	11.1	1	—	39.50	1.10	8.00	5.40	15.60	—	—	—	106.0	42.2	—	7.50
Well L1	19/02E/14	9/9/60	—	—	—	32.00	0.10	7.50	5.60	13.80	—	—	—	86.0	41.8	—	7.50
Well M1	19/02E/16	9/9/60	—	—	2.00	55.10	0.15	9.90	5.50	13.80	—	—	—	106.0	—	—	7.80
Well N1	20/02E/26	8/3/62	—	2	1.00	67.90	0.22	8.30	5.40	11.40	—	—	—	130.0	42.9	—	8.30
Oakbrook well	20/03E/31	8/3/66	—	—	—	—	0.19	—	—	—	—	—	—	—	—	—	—
City of Tacoma																	
Well 11A	20/02E/13H1w	1/31/68	—	—	—	27.40	—	14.80	13.60	5.50	—	0.50	0.10	—	92.9	—	6.90
Well 12A	20/03E/18D1w	10/13/50	—	—	—	19.10	0.01	13.70	11.00	6.80	—	1.20	0.10	—	79.7	—	7.10
Well 2	20/03E/19E1w	1/28/63	—	—	—	26.40	0.01	9.80	3.40	5.40	—	0.30	0.30	—	37.9	—	7.30
Well	20/03E/30N1w	10/30/67	—	—	—	38.80	0.01	15.70	11.00	11.30	—	1.10	0.20	—	84.6	—	6.80
Well	21/02E/34A1w	12/16/66	—	3	—	32.20	0.10	25.20	4.40	8.50	—	1.20	0.20	—	81.1	—	6.60
Fort Lewis Water Dept.																	
Spring	19/02E/19	1/31/67	—	—	—	8.50	0.01	11.00	4.10	5.30	0.90	1.30	—	64.0	44.0	115.0	6.40
Spring	19/02E/19	3/17/64	—	—	—	9.80	—	10.00	4.00	5.40	1.00	1.10	—	68.0	42.0	109.0	6.60
Sull. well	19/02E/30B	12/1/64	12.2	—	—	14.00	0.01	14.00	4.60	5.80	1.10	3.40	—	87.0	64.0	137.0	6.50
Well 3	--	2/6/68	11.0	—	—	31.00	0.13	11.00	5.40	5.20	1.70	0.30	—	98.0	50.0	127.0	7.40
Well 5	--	2/1/68	12.2	10	—	39.00	2.90	6.00	4.70	2.40	0.20	—	—	82.0	27.0	83.0	7.40
Well 6	19/02E/32H2	1/3/62	12.7	—	—	26.00	0.73	15.00	7.70	5.80	1.40	1.30	—	110.0	70.0	162.0	7.10
Well	19/02E/30B2	1/3/62	12.2	—	—	17.00	0.02	14.00	4.90	5.70	1.40	5.40	—	91.0	55.0	140.0	6.40
Well 8	--	3/20/64	11.7	5	—	44.00	1.90	7.50	5.40	6.90	3.00	0.1	—	105.0	40.0	116.0	7.50
Well 13	19/02E/29	2/1/66	12.2	—	—	29.00	0.05	10.00	6.20	5.90	1.50	0.70	—	96.0	50.0	130.0	7.10
Well 14	--	1/31/67	13.9	—	—	27.00	0.02	5.30	3.30	5.10	2.60	—	—	64.0	26.0	82.0	6.90

[a] *Location code is the legal description of the site of the well or, in some cases, spring. For example, 20/02E/30N1w indicates township 20, range 2 east, section 30, 40-acre plot N, and the first well (1w) in that plot.*

[b] Residue after evaporation at 180°C (356°F).

[c] Micromhos at 25°C (77°F).

PRESENT AND FUTURE NEEDS

The primary factors that determine water requirements are population and industrial growth. Since both population and industry are expected to increase at an accelerating rate in years to come, it follows that demands for water will increase at a parallel rate. Estimates indicate that demands for water will far exceed the capabilities of presently developed sources. It is extremely important, therefore, that accurate forecasts of future demand be available so that rational decisions concerning the source and extent of future water sources can be made. Approximately 30 percent of the present developed ground water under recorded rights in the Puget Sound area is in the Tacoma vicinity.

PROJECTED POPULATION GROWTH

Production growth as measured by increased value added, of the major water using industries in the Basin is expected to show an increase of 550 percent between the present and the year 2020. The chemical, petroleum, and food industries, as shown in Figure 8-5, are forecast to become the major industrial forces in the Basin. Food industry production is predicted to grow rapidly through the year 2020, in keeping with projected population increases in this and adjacent basins.

PROJECTED WATER REQUIREMENTS

Total water requirements in the Basin are expected to reach 547 million gallons per day by the year 2020, representing more than a 500 percent increase from 1965 requirements. Table 8-7, 8-8, and 8-9 detail water use requirements for 1980, 2000 and 2020, respectively. Table 8-10 summarizes water use requirements through the year 2020. Figure 8-6 shows graphically the location of water needs.

Municipal

Municipal average daily water requirements are forecast to be 85.5 mgd by 1980, 152 mgd by 2000, and 266 mgd by 2020. By 2020, municipal water requirements will account for approximately 49 percent of total projected water needs for the basin. Per capita water use is projected to increase from approximately 128 gpd at present to about 188 gpd in 1980, 210 gpd in 2000, and 230 gpd in 2020. This increasing per capita water use is in keeping with water use trends observed in other expanding urban areas. See Table 8-10 for a summary of projected rates.

Industrial

Industrial users are expected to continue to be the major water consumers in the Basin. Estimates (Table 8-10) indicate that industrial requirements will increase by more than 500 percent, and will reach approximately 280 mgd by 2020, about 51 percent of total projected water requirements. In 1965, industry consumed some 48.6 mgd, or about 58 percent of the total amount of water consumed in the Basin.

Rural-Individual

In keeping with the predicted population shift to the more urbanized areas, rural-individual water requirements are forecast to drop to about 0.25 mgd by the year 2020, less than one-fourth of 1 percent of total projected water use. Rural-individual consumers presently use about .05 mgd. Present per capita water use is 165 gpd.

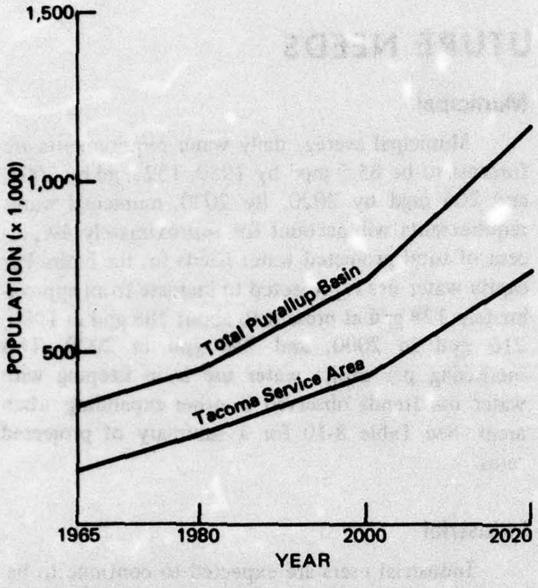


FIGURE 8-4. Projected population growth.

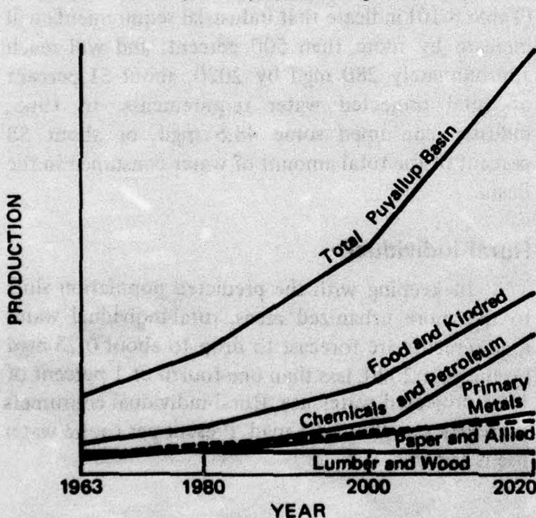


FIGURE 8-5. Relative production growth for major water-using industries.

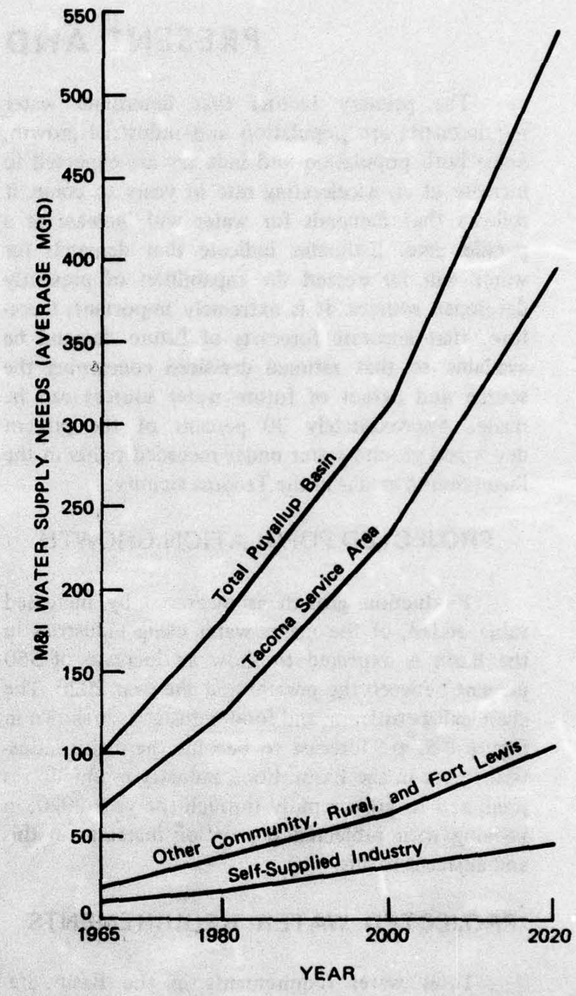


FIGURE 8-6. Location of projected water supply needs.

TABLE 8-7. Projected water use (1980).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Tacoma Service Area	250,000	42.80	60.00	4.80	65.00[a]
Fort Lewis	75,000	—	—	14.20	20.00
Puyallup	30,000	—	—	5.70	8.00
Steilacoom	3,000	—	—	0.60	0.80
Buckley, Sumner, Orting, Bonney Lake, Wilkeson, and other rural community systems	90,800	1.70[b]	2.40	15.60	21.80
Subtotal	448,800	44.50	62.40	40.90	115.60
RURAL-INDIVIDUAL USE	1,000	—	—	0.07[e]	0.10
INDUSTRIAL USE					
Municipally supplied:					
Tacoma:					
Paper and allied	—	49.50	54.50[c]	5.50	6.00[c]
Food and kindred	—	2.40	3.60[d]	0.30	0.40[d]
Chemicals and petroleum	—	11.80	10.60	1.20	1.20
Primary metals	—	7.00	7.00	0.80	0.80
Lumber and wood	—	1.50	1.60[c]	0.20	0.20[c]
Stone, clay, glass	—	0.20	0.30[d]	0.20	0.30[d]
Puyallup:					
Food and kindred	—	—	—	0.02	0.03[d]
Stone, clay, glass	—	—	—	0.14	0.20[d]
Sumner:					
Paper and allied	—	—	—	0.24	0.26[c]
Stone, clay, glass	—	—	—	0.09	0.14[d]
Self-supplied:					
Paper and allied (Chambers Cr.)	—	0.50	0.60[c]	9.00	9.90[c]
Paper and allied (Sumner)	—	—	—	1.60	1.80[c]
Primary metals (Kaiser)	—	—	—	6.50	6.50
Stone, clay, glass	—	0.10	0.15[d]	0.40	0.60[d]
Food and kindred (Sumner)	—	—	—	0.50	0.80[d]
Subtotal	—	73.00	78.50	26.60	29.23
Total[f]	449,800	118.50	140.90	67.60	144.90

[a]Estimated capacity of wells.

[b]Estimated 10 percent served by surface sources.

[c]110 percent of average.

[d]150 percent of average.

[e]Based on 70 gpcd and 100 percent of rural-individual population served by ground water.

[f]Figures are rounded.

TABLE 8-8. Projected water use (2000).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Tacoma service area	423,000	80.00	124.00	8.90	70.00[a]
Fort Lewis	100,000	---	---	21.00	29.00
Puyallup	60,000	---	---	12.60	17.60
Steilacoom	6,000	---	---	1.30	1.80
Buckley, Sumner, Orting, Bonney Lake, Wilkeson, and other rural community systems	130,500	2.70[b]	3.80	24.70	34.60
Subtotal	719,500	82.70	127.80	68.50	153.00
RURAL-INDIVIDUAL USE	1,500	---	---	0.13[e]	0.18
INDUSTRIAL USE					
Municipally supplied:					
Tacoma:					
Paper and allied	---	83.00	92.00[c]	9.20	10.10[c]
Food and kindred	---	4.80	7.20[d]	0.60	0.90[d]
Chemicals and petroleum	---	29.00	27.60	3.10	3.10
Primary metals	---	12.30	12.30	1.40	1.40
Lumber and wood	---	1.60	1.70[c]	0.20	0.20[c]
Stone, clay, glass	---	0.35	0.50[d]	0.35	0.50[d]
Puyallup:					
Food and kindred	---	---	---	0.03	0.04[d]
Stone, clay, glass	---	---	---	0.24	0.36[d]
Sumner:					
Paper and allied	---	---	---	0.40	0.44[c]
Stone, clay, glass	---	---	---	0.16	0.24[d]
Self-supplied:					
Paper and allied (Chambers Cr.)	---	0.80	0.90[c]	15.00	16.50[c]
Paper and allied (Sumner)	---	---	---	2.70	3.00[c]
Primary metals (Kaiser)	---	---	---	11.50	11.50
Stone, clay, glass	---	0.17	0.25[d]	0.70	1.00[d]
Food and kindred (Sumner)	---	---	---	1.00	1.50[d]
Subtotal	---	130.60	142.45	46.58	49.88
Total[f]	721,000	213.30	270.40	115.20	203.10

[a]Estimated capacity of wells.

[b]Estimated 10 percent served by surface sources.

[c]110 percent of average.

[d]150 percent of average

[e]Based on 90 gpcd and 100 percent of rural-individual population served by ground water.

[f]Figures are rounded.

TABLE 8-9 Projected water use (2020).

System	Estimated population served	Surface water usage (mgd) Average daily	Surface water usage (mgd) Maximum monthly	Ground water usage (mgd) Average daily	Ground water usage (mgd) Maximum monthly
MUNICIPAL USE					
Tacoma service area	730,000	151.00	210.00	17.00	75.00[a]
Fort Lewis	125,000	—	—	29.00	40.00
Puyallup	90,000	—	—	21.00	29.00
Steilacoom	10,000	—	—	2.30	3.20
Buckley, Sumner, Orting, Bonney Lake, Wilkeson, and other rural community systems	200,400	4.60[b]	6.50	41.00	57.00
Subtotal	1,155,400	155.60	216.50	110.30	204.20
RURAL-INDIVIDUAL USE	2,300	—	—	0.25[e]	0.35
INDUSTRIAL USE					
Municipally supplied:					
Tacoma:					
Paper and allied	—	105.00	115.00[c]	11.60	12.80[c]
Food and kindred	—	8.80	13.00[d]	1.10	1.60[d]
Chemicals and petroleum	—	70.50	68.00	7.60	7.60
Primary metals	—	21.60	21.60	2.50	2.50
Lumber and wood	—	1.50	1.60[c]	0.20	0.20[c]
Stone, clay, glass	—	0.80	1.20[d]	0.80	1.20[d]
Puyallup:					
Food and kindred	—	—	—	0.06	0.09[d]
Stone, clay, glass	—	—	—	0.60	0.90[d]
Sumner:					
Paper and allied	—	—	—	0.50	0.60[c]
Stone, clay, glass	—	—	—	0.36	0.54[d]
Self-supplied:					
Paper and allied (Chambers Cr.)	—	1.00	1.10[c]	19.00	21.00[c]
Paper and allied (Sumner)	—	—	—	3.40	3.80[c]
Primary metals (Kaiser)	—	—	—	20.20	20.20
Stone, clay, glass	—	0.38	0.60[d]	1.60	2.40[d]
Food and kindred (Sumner)	—	—	—	1.80	2.70[d]
Subtotal	—	209.58	222.10	71.32	78.13
Total[f]	1,157,700	365.20	438.60	181.90	282.70

[a] Estimated capacity of wells.

[b] Estimated 10 percent served by surface sources.

[c] 110 percent of average.

[d] 150 percent of average.

[e] Based on 110 gpcd and 100 percent of rural-individual population served by ground water.

[f] Figures are rounded.

TABLE 8-10. Summary of projected water needs.

Use	Year	Estimated population served	Surface water usage (mgd) Average daily	Maximum monthly	Ground water usage (mgd) Average daily	Maximum monthly	Total usage (mgd) Average daily	Maximum monthly
Municipal	1965	344,455	21.1	28.9	22.4	98.3	44.1	127.2
	1980	448,800	45.5	62.4	40.9	115.6	86.41	178.00
	2000	719.500	82.7	127.8	68.5	153.0	151.2	280.8
	2020	1,155,400	155.6	216.5	110.3	204.2	265.9	420.7
Industrial	1965	--	41.5	49.3	14.6	16.4	56.1	65.7
	1980	--	73.0	78.5	26.6	29.2	99.6	107.7
	2000	--	130.6	142.6	46.6	49.9	177.2	192.5
	2020	--	209.6	222.1	71.3	78.1	280.9	300.2
Rural-Individual	1965	745	0.0	0.0	0.0	0.1	0.0	0.1
	1980	1,000	--	--	0.1	0.1	0.0	0.1
	2000	1.500	--	--	0.1	0.2	0.1	0.2
	2020	2,300	--	--	0.3	0.4	0.3	0.4
Totals	1965	345,200	63.2	78.2	37.00	114.80	100.2	193.00
	1980	449,800	118.5	140.9	67.6	144.9	186.1	285.8
	2000	721,000	213.3	270.4	115.2	203.1	328.5	473.5
	2020	1,157,700	365.2	438.6	181.9	282.7	547.1	721.3

Note: Usage figures are rounded to one decimal place.

MEANS TO SATISFY NEEDS

GENERAL

The projected annual water use is expected to reach 550 mgd by the year 2020. This is an increase of approximately 450 mgd over the 1965 average use. Optimum or peak water requirements will be almost two times this average or nearly 2,100 mgd. Table 2-12 and 2-13, the Area Plans, summarize the Basins' annual average and optimum requirement. Table 8-10 M&I Water Supply Needs, reviews the needs of the major water systems and/or users in the Basin.

The city of Tacoma, largest water purveyor in the Basin, uses both surface and ground water to meet the peaks of its municipal and industrial consumers. They divert surface water from the Green River, to a settling reservoir southeast of Tacoma where it is chlorinated and delivered to the storage and distribution systems. The ground water, although very sustantial, is used only for meeting peaks or during maintenance on the Green River transmission line or periods of high turbidity.

Surface water is expected to supply nearly 67 percent of the total water used within the Basin, with the remainder supplied by ground water. The average production per recorded well of 0.7 mgd is quite indicative of the quantity of ground water available. Several wells produce well over 5 mgd.

Most all of the remaining communities in the basin, unless served by Tacoma, rely upon ground water for supplying needs. The largest of these service areas are Lakewood, Fort Lewis, and Puyallup.

BASIN PLANS

The Selected Plan, Table 8-12, shows the expected development for the systems within the basin:

Tacoma is expected to continue development of the Green River until approximately the year 2005, at which time they will also develop a site on the Puyallup River. The city's ground water development will be expanded concurrently with the surface water supply. This ground water source would augment the surface water and be utilized during times of peak demand or unacceptable turbidity in the surface supply.

The city of Puyallup in the Selected Plan is propsed to connect to the Green River transmission

line to Tacoma. This would require Puyallup to provide a reservoir to be used for storage and turbidity removal. If this reservoir were large enough to be used for meeting peak demands and Puyallup could contract for a certain amount of water daily, Tacoma could wholesale water to the City.

In the Selected Plan, Fort Lewis is listed as remaining on a ground water source. The city of Tacoma Water Division does not anticipate supplying water to either Fort Lewis or McChord Air Force Base. McChord is presently served by Fort Lewis.

The Alternative Basin Plan calls for the Tacoma Water Division to develop the Green River to optimum capacity. In 1985, however, it calls for a development on the Skokomish River in the West Sound Basins. This would necessitate a transmission line approximately 50 miles long which would have to cross the Tacoma Narrows Bridge. This source, however, would be able to supply Shelton and all of the Southern Kitsap Peninsula, presently an area with inadequate water supplies. A promising plan (not considered) would be another transmission line from the Skokomish River to serve the area in and around Olympia (Nisqually-Deschutes Basin) as the need arises.

In the Alternative Plan, the remaining communities are expected to continue development of present sources–mainly local ground water developments to meet local needs.

Surface and ground water supplies can be economically utilized by rural-individual or small community effort water systems, such as wells and small surface diversions and package treatment plants; 90 percent of this coming from ground water sources. The major means are to enlarge the present pumping, treatment and distribution systems to handle the peak water demands.

Tables 8-12 and 8-13, The Selected and Alternative Plans, respectively, include costs for supply and transmission, treatment, pumping, and chemicals. Projected annual income is also included. Tables 2-12 and 2-13, the Area Selected and Alternative Plans, respectively, list the storage and distribution costs for each Basin. These costs will remain the same for both plans. Table 8-10, Summary of Projected Water Needs, shows the level of need to 2020 from all sources.

FINANCE

Annual income as taken from Tables 2-12 and 2-13 for the Selected and Alternative Plans indicates the amount of money available to apply for bond service (approximately 20 percent of the total annual income).

The following figures indicate the monies available for bond service and the capital expenditures amotrized for 30 years at 5% for the Selected and Alternative Plans.

Year	Annual Bond Service Available (x $1,000)	Annual Amortized Cost (x $1,000) Selected Plan	Annual Amortized Cost (x $1,000) Alternative Plan
1965	$1,620	$790	$ 670
1980	2,150	2,440	1,970
2000	3,840	4,420	4,750
2020	6,350	6,980	7,440

Costs as indicated by the Engineering News Record Index are presently doubling every 15 years. It is projected that by 1980 or sooner the Puyallup Basin will be unable to bond for the required water supply development, and future construction would involve extraordinary financial burdenn in relation to the Basin's economic resources or a series of major value rate increases.

TABLE 8-11. M & I Water Supply-Capital Improvements
Puyallup Basin

	M. G. D.			
	Present		Future	
	1965	1965-1980	1980-2000	2000-2020
Population Served	158,000	250,000	432,000	730,000
TACOMA				
Optimum	158.3	251.0	435.8	726.6
Capital Improvements	81.6	92.7	184.8	290.8
Population Served	60,000	75,000	100,000	125,000
FORT LEWIS				
Optimum	39.5	49.4	65.8	82.3
Capital Improvements	24.5	9.9	16.4	16.5
Population Served	15,000	30,000	60,000	90,000
PUYALLUP				
Optimum	10.1	19.9	39.9	60.2
Capital Improvements	8.1	9.8	20.0	20.3
Population Served	111,455	93,800	139,500	210,400
SMALL & RURAL COMMUNTIY SYSTEMS				
Optimum	74.0	62.1	90.5	139.5
Capital Improvements	53.4	—	16.5	49.0
Population Served	—	—	—	—
SELF SUPPLIED INDUSTRY				
Optimum	10.6	20.4	34.7	51.8
Capital Improvements	0.6	9.9	14.3	17.1
Population Served	344,455	448,800	728,500	1,155,400
TOTAL				
Capital Improvements	168	122	252	394

NOTE: Figures are rounded.

TABLE 8-12. M & I Water Supply Use Planning—Present to year 2020 Selected Basin Plan Puyallup Basin

					OPTIMUM CAPACITY M G D		1967 THOUSAND DOLLARS					
							AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
TACOMA												
Present	SW	Green River Diversion	Exist.	68	72	72					20	4,891
Present	GW	Local Ground Water	Exist.		62	62				704		
Present	SW	ADD: 23.7mgd	1985		23	23	3,081	1,778				
1980	SW	Green River	1975	128	93	93	11,700	6,750		1,346	52	7,475
2000	SW	Green River	1990	235	90	90	11,700	6,750		2,466	94	13,724
	GW	Local Ground Water			95	95	5,700					
2020	SW	[a] Puyallup River Near Electron	2005	400	210	210	24,300	13,700		4,210	160	23,418
	GW	Local Ground Water			90	90	4,200					
					735	735	$ 60,681	$28,978				
TACOMA SELECTED PLAN TOTAL							$89,659					
PUYALLUP												
Present	GW	Local Ground Water	Exist.	2	2	2				20		234
Present	GW	ADD: 8.1mgd	1985		8	8	486					
1980	SW	[a] Water Division, City of Tacoma (Divert from Transmission Line)	1978	6	10	10	1,274	735		62		360
2000	SW	(Divert from Transmission Line)	1990	13	20	20	3,600	1,500		136		769
2020	SW	(Divert from Transmission Line)	2015	21	20	20	2,639	1,523		227		1,226
					60	60	$ 7,999	$3,758				
PUYALLUP SELECTED PLAN TOTAL							$11,757					
FORT LEWIS												
Present	GW	Local Ground Water	Exist.	8	15	15				84		657
Present	GW	ADD: 24.5mgd	1985		25	25	1,470					
1980	GW	[a] Nisqually River—Local Ground Water	1975	14	10	10	594			149		1,150
2000	GW	Nisqually River—Local Ground Water	1995	21	16	16	984			220		1,726
2020	GW	Nisqually River—Local Ground Water	2010	29	16	16	990			304		2,117
FORT LEWIS SELECTED PLAN TOTAL					82	82	$4,038					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water	Exist.	15	19	19				162		1,752
Present	GW	ADD: 54.7mgd	1985		54	54	3,282					
1980	SW	[a] Water Division, City of Tacoma	1975	18	62	62	7,693	4,207		191	7	1,051
2000	SW	Water Division, City of Tacoma	1995	29	28	28	3,145	2,237		307	12	1,051
2020	SW	Water Division, City of Tacoma	2010	49	49	49	6,370	3,675		512	20	2,862
					139	139	$ 20,490	$ 10,119				
SMALL & RURAL COMMUNITY SYSTEMS TOTAL							$30,609					
SELF SUPPLIED INDUSTRY												
Present	GW	Local G Water	Exist.	10	11	11				105		3
1980	GW	Local G Water	1980	18	11	11	660			189		6
2000	GW	Local G Water	1995	30	15	15	900			315		10
2020	SW	Local G Water	2015	46	17	17	2,210			463		15
					54	54	$ 3,770					
SELF SUPPLIED INDUSTRY TOTAL							$3,770					
SELECTED PLAN TOTAL							$139,840					

[a] Initial development.

[b] Does not include storage and distribution costs: See Area Means to Satisfy Needs section.

[c] All figures are rounded.

TABLE 8-13. M & I Water Supply Use Planning—Present to year 2020 Alternate Basin Plan Puyallup Basin

					OPTIMUM CAPACITY MGD		1967 THOUSAND DOLLARS: AMORTIZED CAPITAL COST[b]			MAINTENANCE AND OPER.		
Plan Level	Source	Development	Year of Devel.	Projected Annual Wtr. Use MGD	Supply	Transm.	Supply & Transm.	Treat-ment	Iron Removal	Pumping Power	Chem.	Total Annual Income
TACOMA												
Present	SW	Green River Diversion	Exist.	67	72	72						
Present	GW	Local Ground Water	Exist.		62	62				704		4,891
Present	GW	Local Ground Water	1965		23	23	1,422					
1980	SW	Green River	1970	128	95	95	11,700	6,750		1,346	52	7,475
2000	SW	[a] South Fork Skokomish River	2000	235	185	185	24,050	13,875		2,466	94	13,724
2020	SW	South Fork Skokomish River	2015	401	155	155	18,800	10,900		4,210	160	23,418
2020	SW	Green River			135	135	16,200	9,400				
					657	657	$72,172	$40,925				
TACOMA ALTERNATIVE PLAN TOTAL							$113,097					
PUYALLUP												
Present	GW	Local Ground Water	Exist.	2	2	2				20		234
Present	GW	Local Ground Water	1965		8	8	486					
1980	GW	Local Ground Water	1975	6	10	10	588			62		350
2000	GW	Local Ground Water	1995	13	20	20	1,200			135		759
2020	GW	Local Ground Water	2015	21	20	20	1,218			227		1,226
PUYALLUP ALTERNATIVE PLAN TOTAL					60	60	$3,492					
FORT LEWIS												
Present	GW	Local Ground Water	Exist.	8	15	15				84		657
Present	GW	Local Ground Water	1965		25	25	1,470					
1980	SW	[a] Nisqually River—Intake and Treatment	1975	14	10	10	1,287	743		149	6	1,150
2000	SW	Nisqually River—Intake and Treatment	1990	21	16	16	2,132	1,230		220	8	1,726
2020	SW	Nisqually River—Intake and Treatment	2010	29	16	16	2,145	1,237		304	12	2,117
					82	82	$ 7,034	$ 3,210				
FORT LEWIS ALTERNATIVE PLAN TOTAL							$10,244					
SMALL & RURAL COMMUNITY SYSTEMS												
Present	GW	Local Ground Water	Exist.	15	19	19				161		1,752
Present	GW	ADD: 54.7mgd	1965		54	54	3,282					
1980	GW	No Additional Need		18						191		1,051
2000	GW	Local Ground Water	1990	29	16	16	990			307		1,694
2020	GW	Local Ground Water	2010	49	49	49	3,940			512		2,862
SMALL & RURAL COMMUNITY SYSTEMS ALTERNATIVE PLAN TOTAL							$8,212					
SELF SUPPLIED INDUSTRY (No Feasible Alternative)							$3,770					
ALTERNATIVE BASIN PLAN TOTAL							$138,815					

[a] Initial development.

[b] Does not include storage distribution costs: See Area Means to Satisfy needs section.

[c] All figures are rounded.

Nisqually-Deschutes Basins